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DISPATCHES FROM THE FUTURE

Ten of the brightest minds in science fiction imagine how we will live—on Earth and beyond—in the decades and centuries to come.

PAGE 58



POPULAR SCIENCE INDIA CONTENTS

Featuring



WISH YOU WERE HERE

You won't need a rocket to experience space. New high-altitude balloons promise a slower, gentler trip (and a bar).

KALEE THOMPSON

PAGE 42



BUGGED

We live in fear of the microbes that inhabit our homes and buildings. But our health might depend on preserving theirs.

RINKU PATEL

PAGE 48

INSTRUCTIONS NOT INCLUDED

What does the disappearance of the common manual say about us?

MARK SVENVOLD

PAGE 54

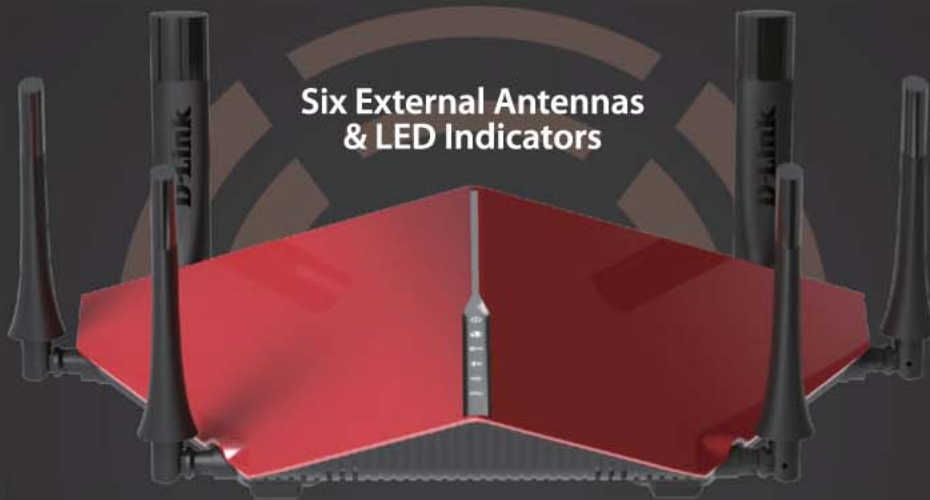
ON THE COVER

A World View Experience balloon.

Illustration

by PriestmanGoode

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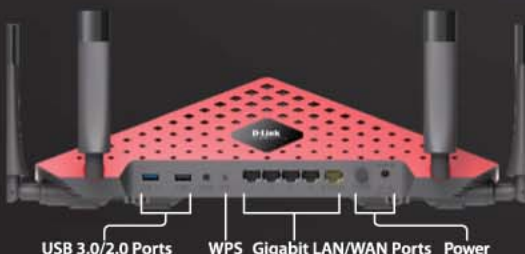
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FEED

- 08 From the Editor
- 10 A Bit About Us
- 12 Peer Review

NOW

- 13 An e-bike to accelerate commutes
- 14 Ten things we love this month
- 16 Cadillac's luxury lightweight hybrid
- 18 Backcountry gear finds a new purpose
- 20 Now you can own a Tesla (battery)
- 22 A virtual camera for 3-D footage
- 24 World's first foldable electric scooter
- 26 Speakers that aim sound straight at you
- 28 Surfboards made by a rocket scientist
- 29 Utilities Available Now!
- 32 First Drive / Tesla Model S P85
- 34 Road Test / Kawasaki Z250

NEXT

- 35 Lightning, dissected
- 36 What's really on your dinner plate?
- 37 Vint Cerf on the future of the Internet
- 38 A helicopter that can fly like a jet
- 40 Diamonds grown in a lab
- 41 Your next pet should be a robot

MANUAL

- 69 Track your home's health
- 71 A fire extinguisher with bass
- 72 Rise of the MegaBot

END MATTER

- 74 Ask Us Anything: Could a lion live off veggie burgers?

13
Now



69
Manual



35
Next



74
End Matter



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Editor: Girish Mallya

Future Course

While Mars One is planning a flight straight out to another planet in 2016, an easier journey into outer space is in the works. And that is not as distant a dream as you might think. Read all about it in our pages in 'Wish You Were Here.'

Right after, there's something to pull you right back to earth. Microbes. You may sterilise your immediate environment, ban your baby from eating mud from the playground, and wipe your hands with sanitizer every time you touch invisible dust. But what you don't realise is that as you do this, you may actually be eliminating these organisms that are possibly rather important for your healthy survival. Something to think about, and read about in this August issue in the story 'Bugged.' That and other stories in this month's issue should keep you hooked.

On July 27, India lost one of its greatest minds, noblest souls and one of its most influential scientific leaders. Let us take a moment to remember Abdul Kalam, the man who gave the India a reason to stand tall and proud in front of the world. He passed away doing what he enjoyed the most: Teaching. RIP Abdul Kalam, the visionary who inspired millions.

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Contributors



Rinku Patel

While we know that the human microbiome protects our health, "what's overlooked," says science journalist Rinku Patel, "is the environment where we pick up the trillions of foreigners that shape our immune system." Writing "Bugged" (page 40), about the microbes that share our real estate, put her on a mission. She now leaves her doors and windows open so the microbes can come in.



Jarren Vink

Photographer Jarren Vink is accustomed to making static objects look great. But the Tesla Powerwall (page 16) proved a challenge. "It looks like a giant cellphone," Vink says. Despite the battery's unassuming design, it was wheeled into his studio in a wooden crate, stamped with the Tesla logo, worthy of an Old Masters shipped from the Louvre. "Too bad we couldn't shoot the crate," says Vink.



Kalee Thompson

Contributing editor Kalee Thompson thought of space tourism as a pricey jaunt for the .001 percent. But after reporting "Wish You Were Here" (page 34), she now sees the appeal. Balloon trips to the stratosphere, albeit not quite space, are "more accessible," Thompson says. And, she adds, they offer a serene group experience, "something you can take Grandma on to celebrate her 100th birthday."



Sam Weber

We asked illustrator Sam Weber to envision sci-fi medicine in "Dispatches from the Future" (page 50). When searching for inspiration, he had to look no further than his girlfriend's recent Lasik eye-surgery. "Contemporary eye surgery is terrifying," Weber says. He even used his girlfriend as the model for his illustration—with an orange cornea, and glowing white filaments shooting from her face.



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Peer Review

Loved reading the feature about the Hyperloop! We keep thinking Japanese bullet trains are the fastest but this sounds amazing! I wonder if it will actually work! Hope so. Really enjoyed the July issue. Lots to read! And great gadgets!

Manish Gupta, Pune

The Volvo XC90 is just the car that we need on Indian roads. I mean a car that has superbrakes to prevent accidents will be a sell-out here. We keep reading about so many people dying from road accidents alone, that a car like this can make a difference. We should really put in more R&D in our own cars to see what can be done. And we need to improve the road safety part of course! Maybe you could carry an article about that in one of your issues?

Hetal Shah, Mumbai

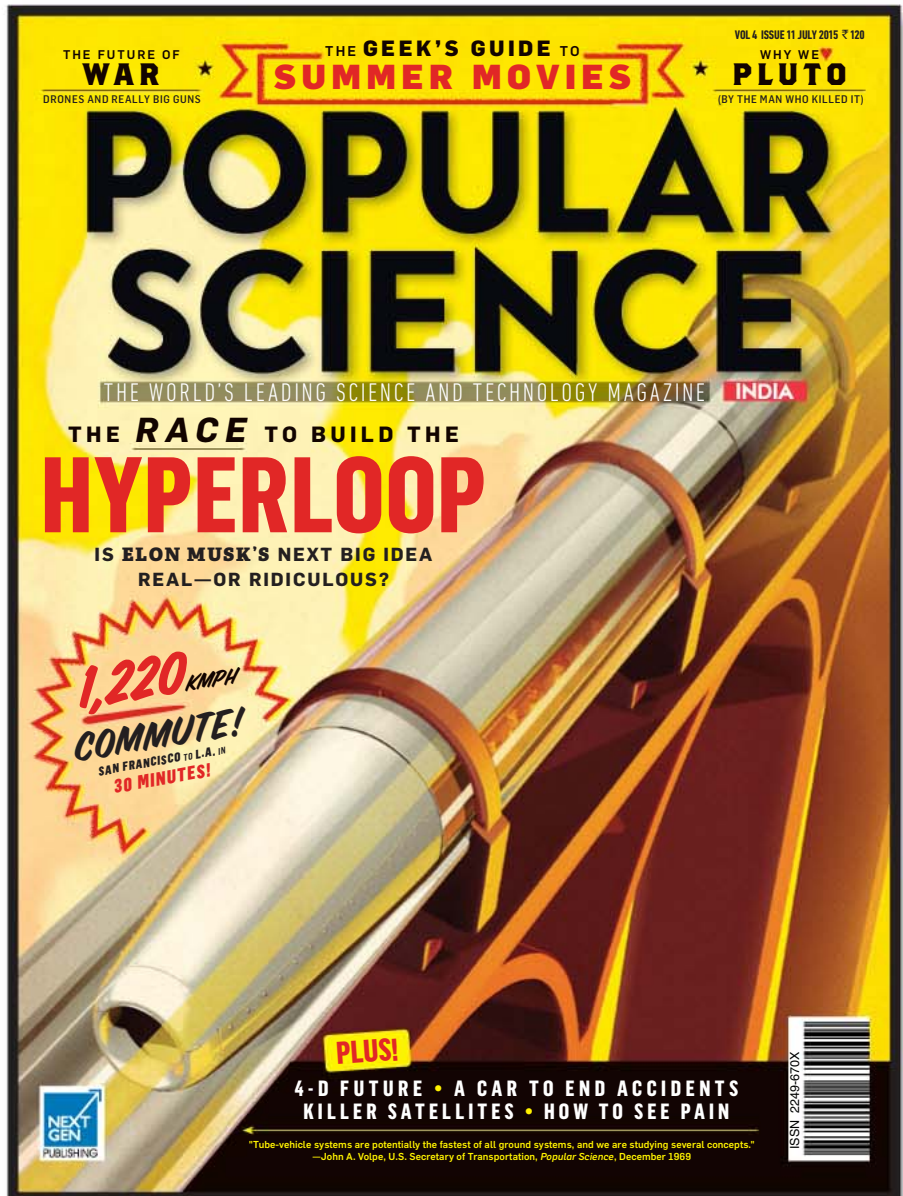
The Gixxer SF looks so good! I think the car and bike reviews in PopSci are very informative & useful. It's always helpful to read about first-hand experience of a test drive to get an idea about the vehicle. I always like the car and bike reviews. And the new gadgets you all talk about.

Ritesh Thapar, New Delhi

I think your cover story in July was really very nice. This Hyperloop sounds very exciting. Let's hope we actually get to see it happen. Can you publish articles about

how much India uses scientific technology in our infrastructure development?

Bijoy Pradhan, Mumbai



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TAKE HILLS WITHOUT BREAKING A SWEAT

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↓
Commuters love nothing more than blowing past hipsters on fixies. That's one reason the 48 kmph Stromer ST2 electric bike is a total joy for urban cyclists. With a 144.8-km range—twice that of other e-bikes—you can forgo work altogether and head for the hills.

The ST2 packs a 48-volt battery in the frame's down tube, evenly distributed for balance—another e-bike first. It also stretches battery life by way of regenerative braking. A gyroscope and accelerometer further boost efficiency by adjusting battery output while the bike is in motion.

Pedalers love the peripherals too. An onboard touchscreen displays your speed and power mode. Riders can customize the level of motor assistance by programming a custom profile; torque, pedal sensitivity, and power-assist level can all be changed on a whim or saved for later use. The bike also connects to Global System for Mobile Communications (GSM) data networks on its own, without a data plan, so it's always connected. In the event it's stolen, GPS allows you to track it with your smartphone and lock it down remotely. Oh, and it looks like a two-wheel urban assault vehicle worthy of the Dark Knight. Eat your hearts out, Boy Wonders. **DAN KOEPPPEL**



STROMER ST2

Price ₹4,54,350

Max Range

144.8 km

Weight

28 kg



Obsessed

Some things are just...better

LINDSEY KRATOCHWILL

1 DEATH STAR LIGHT-UP BEACH BALL

SwimWays lets you flaunt your *Star Wars* fanaticism ahead of this year's big-screen installment. It might not have planet-destroying lasers, but with embedded LEDs, you can use your imagination. ₹455

2 CONNECTED COLLAR

DogTelligent's Connected Collar quiets unruly pups—and trains them to stay that way. An ultrasonic speaker emits a sound that discourages barking, plus the collar works as a virtual fence and leash. ₹8,450

3 LUNA

Much of our lives is spent sleeping. So the Luna smart mattress cover uses sensors to track your sleep, and integrates with smart-home devices to control lights or a thermostat to create the optimal sleeping environment. ₹5,275

4 HARDWARE STORE SAW

Brooklyn Tool & Craft's short-bladed saw has a unique tooth design that can handle both rip and crosscut jobs. The blade's diagonal scales and measuring tools help you convert to metric or check angles without reaching for the toolbox. ₹9,685

5 WASTED SEA STAR PURPLE PALE ALE

Next time you reach for a cold one, the brewers at Rogue

hope you'll think of the disease that's killing millions of starfish. The brewery teamed with the Partnership for Interdisciplinary Studies of Coastal Oceans to create this pale ale. Some proceeds will go toward researching sea star wasting syndrome. ₹239

6 MAP OF LIFE

For backyard ecologists and curious travelers, Yale University's app makes learning about nature simple. Using your location, it helps you identify, say, what species of frog or tree you've found, and can alert you to others likely nearby. Free

7 BRAUN SERIES 9 SHAVER

Braun's most efficient shaver yet isn't just great at eliminating tough hairs that grow in strange directions. Its pivoting head and individually floating cutting elements can make a three-day beard disappear with fewer strokes. ₹22,750

8 SURVIVAL LACES

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9 THE MAN WHO WASN'T THERE

Science journalist Anil Ananthaswamy's new book explores quirks of the mind with stories about people who lose their sense of self and believe they aren't alive. ₹1,755



SLEEP SMARTER

10 BIG BLUE LIVE

Dive deep into the ecosystem of the Monterey Bay National Marine Sanctuary with the BBC and PBS. Over the course of two weeks, they'll air—on TV, streaming online, and through social media—a live show that takes viewers to the wilds of the West Coast to see humpback whales, sea otters, great white sharks, and other creatures up close. Aug. 31



FROM TOP LEFT: COURTESY SWIMWAYS; COURTESY DOGTELLENT; COURTESY ROGUE; COURTESY PENGUIN RANDOM HOUSE; COURTESY TYSON V. RININGER / PBS; COURTESY BRAUN; COURTESY WASATCH OUTDOORS; COURTESY LUNA; COURTESY YALE UNIVERSITY; COURTESY BROOKLYN TOOL & CRAFT



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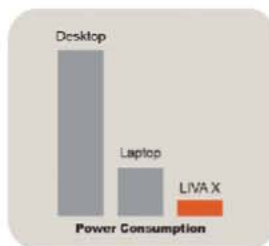
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CADILLAC INTRODUCES LIGHTWEIGHT LUXURY



Weight is a problem when it comes to fuel economy. The heavier something is, the more energy you burn moving it down the road. The engineers at Cadillac tackled this problem head-on with the new CT6. Rather than relying on expensive carbon fiber or heavy

steel, they created a lightweight chassis from a new composite. The result marries 11 materials including high-strength steel and lightweight aluminum, shaving 89.8 kg off the traditional chassis.

Available as a hybrid—making it the first full-size electric luxury sedan—the car's drivetrain takes fuel efficiency a step further. An 18.4 kilowatt-hour lithium-ion battery powers an electric variable transmission capable of boosting acceleration

without spasmodic jolts. As for the gas-powered half, it's a small 2.0-liter four-cylinder engine. Combined, they provide the CT6 with a respectable 335 horsepower.

All this adds up to a luxury hybrid with more than double the mileage of its gas-powered counterpart. But true Caddy lovers will appreciate the new agility brought by the car's electric engine. The CT6's 1,814-kg rivals might want to invest in a treadmill. **JOSEPH OROVIC**



DESIGN OF THE MONTH

2016 Dodge Viper ACR

The 2016 Dodge Viper American Club Racer unabashedly exploits every downforce-enhancing body attachment imaginable. It sports a massive carbon-fiber rear wing,

a detachable extension for the front splitter, sinister-looking dive planes, and a hood with removable louvers. At 284.8 kmph, it's the fastest street-legal track Viper ever.



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The Setup

1

MSR SE200 COMMUNITY CHLORINE MAKER

For 25 years MSR has made light-weight, portable water filters for backpackers and U.S. soldiers. It has now employed that expertise to create the SE200. It's a chlorinator that uses table salt, water, and a 12-volt car battery to make enough chlorine to kill waterborne pathogens, turning a 208-liter drum of tainted water drinkable. Health workers will use it to supply remote villages with clean water. ₹15,535



3

GRAVITYLIGHT

Kerosene lanterns are standard in developing countries. But they're expensive

and emit deadly fumes. The World Bank estimates that for the 780 million women and children who breathe them in, it's like smoking 40 cigarettes a day. To clear the

air, GravityLight's upcoming GL02 powers lanterns with kinetic energy. A 12-kilogram weight hanging from the lantern drops 1.8 meter on a high-torque drive sprocket,

which connects to a DC generator. A three-second drop powers an LED for 20 minutes. The company has tested it in more than 1,300 off-grid households. **Price not set**



2

GOSUN SPORT

GoSun's portable solar stove was designed for car camping and barbecues. Parabolic reflectors

surround and heat a borosilicate glass tube—which holds your food of choice—up to 287.8°C. In full sun, it can cook a hot dog in less than 10 minutes. Last winter the company brought a less-expensive model of the stove to Guatemala, where it reduced cooking costs significantly.

₹16,185



BACKCOUNTRY GEAR TO SAVE YOUR LIFE—AND THE WORLD

Cooking burgers, purifying water, and lighting a campsite all require cleverly designed gear. But that doesn't have to be exclusive to the backcountry. Similar conditions exist all over the developing world. Now the gear that outdoor companies have spent years developing for adventurers and survivalists are playing important roles in low-resource areas. **HEATHER HANSMAN**

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You Can Finally Afford a Tesla

Installing solar power at home is good for your wallet and the environment, but storing it is no easy feat. Until recently, the process involved connecting a series of finicky, fragile, glorified car batteries. The Powerwall, unveiled by Tesla Motors CEO Elon Musk

earlier this spring, is no DIY project. It's a simple plug-and-play home lithium-ion battery aimed at changing the way people think about and store energy.

The Powerwall's large curvy case is the size of a futuristic boogie board, and it's meant to be mounted on a wall like art. It draws electricity from the grid when demand and rates are low or sucks it from solar panels atop your roof (panels sold separately). The energy is saved for use during peak power-demand hours, when utilities raise rates, or as backup during a power outage.

It fits in nicely with another Musk-backed company: SolarCity. But its creators say that Tesla Motors' prior research into electric cars is what made it possible.

The Powerwall comes in two models with different storage capacities, prices, and purposes: The 7-kilowatt-hour model costs \$3,000 and is designed specifically for daily solar-energy collection and discharging; the 10-kilowatt-hour model costs \$3,500 and is meant to store energy for weeks at time as backup. Up to nine Powerwalls of each type can be connected for even greater capacity.

In America, the number of solar installations is small but growing. And with the price of solar energy systems steadily declining (6 to 8 percent a year since 1998, according to the U.S. Department of Energy), analysts expect solar energy to reach price parity with the larger, fossil-fuel-dominated electrical grid as early as next year.

Solar junkies aren't waiting. Musk recently said the Powerwall was sold out through mid-2016, though customers can still place orders online. Based on potential future savings, it might be well worth the wait. **CARL FRANZEN**



TESLA POWER-WALL

Dimensions

51.2" x 33.9" x 7.1"

Weight 100 kg

Colors Prototypes include white, charcoal, red, and blue

Models

• 10 kWh

₹2,27,500

For backup

• 7 kWh

₹1,95,000

For daily cycle

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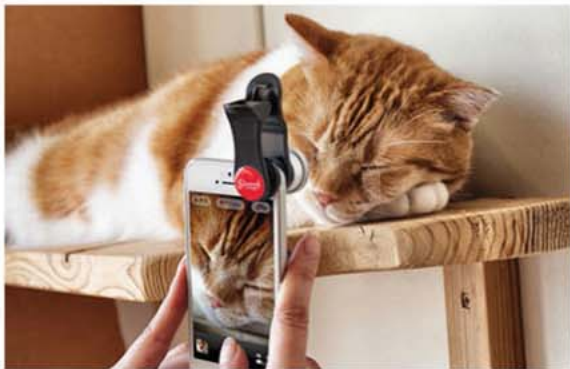


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5.7

Number, in millions, of virtual-reality devices projected to be sold in 2015



The Camera That Makes Virtual Reality Feel Real



Facebook, Google, HTC, and plenty of startups are betting big on virtual reality. But VR headsets could join the graveyard of overhyped gadgets if there's nothing to watch. Luckily production houses and filmmakers are working on realistic virtual experiences. Though it's going to take more than a camera that can shoot 360 degrees of footage.

Arthur van Hoff, co-founder of

virtual-reality studio Jaunt VR, is a tinkerer. At age 12 he made a working photocopier out of LEGOs and a felt-tip pen, and he used that ingenuity to build the Jaunt prototype camera. It's made of 16 modified GoPro cameras housed in a 3-D-printed carousel. Jaunt's fleet of 20 has logged hundreds of hours of footage, like Paul McCartney performing "Live and Let Die" and Yahoo Screen's sci-fi comedy *Other*

Space. But the real innovation comes after the shoot.

As is, the picture looks flat (Jaunt calls it "2-and-a-half-D"). For normal 3-D movies, a pair of stereoscopic cameras shoot two versions of each scene. They're split into separate feeds—one for the left eye, one for the right—and projected on top of one another, and polarized glasses trick the brain into seeing depth.

Things get messy when 16 cameras are shooting in 16 directions. So Jaunt created a virtual camera. Software synchronizes all the video streams to make it appear as if they were shot by a single camera at the center of the array, and turns the footage into two feeds for the left eye and right eye. Now when the evil villain lunges at you, it feels so realistic, you might forget you can take off the headset.

ANDREW ROSENBLUM

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Max distance:
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capacity of 45°)



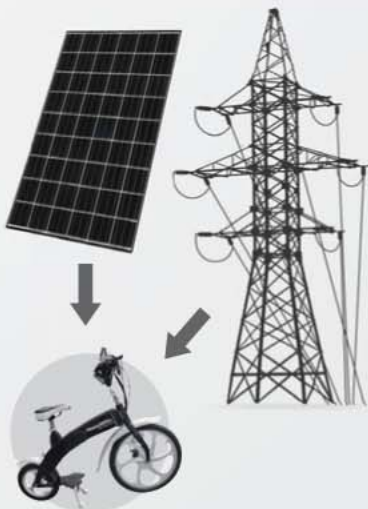
World's first foldable electric scooter

Story by **R Srinivasan**

It can be conveniently stored to fit in the boot of that car, can be charged using electricity and in remote areas without access to the grid, it can be charged using solar energy.

For those who want a scooter that can be conveniently stored and does not use polluting fossil fuels, NanoWin Technology Co Ltd claims to have come up with the world's first foldable electric scooter that employs solar charging. Charging can be achieved by a solar panel, which is optional for people in rural areas with no access to the grid. The compact, light-weight (16-20 kg) scooter can be easily carried in public transport or easily folded to fit in the boot of a car. Manufactured in Taiwan and China, it has a waterproof motor with a water resistance level of IP68 so it can even be driven in flooded areas for a long time. It has three speed modes -16 kmph, 25-26 kmph and 35 kmph with a climbing capability of up to 45 degrees while other brands offer only 12-15°. Depending on the type of battery (9, 12, 18 or 24 AH/60VDC) used, the vehicle can travel for 55, 75, 110, or 150 km. The battery charging time varies, depending on the capacity, and ranges from 2 to 4 hours.

CAN BE CHARGED BY SOLAR PANEL OR GRID POWER



HOW IT CAN BE FOLDED



1-3 seconds



4-8 seconds

SEATING AND MAX PERMISSIBLE WEIGHT

It has three optional seating capacities:

1. With parent-child - maximum loading capacity is 150 kg.
2. With husband and wife - maximum loading capacity up to 160 kg.
3. With wheel chair seat for elderly or disabled - maximum loading capacity up to 200 kg. It has two riding modes – ride it as a electric scooter or stand on it as in a kick scooter.

Instrument panel has a display screen to show the current speed, total km from the beginning or for a particular trip, information about low battery, etc. For safety, the scooter has a password and users can set up their own passwords so there is no need to carry keys.

COLOUR OPTIONS

Apart from black and leopard prints, the company will customise it if the orders are for over 1,000 pieces.

COST

The company's price to end-users will be about USD 740-800. But its export price to the agent will be much lower than the end-user's price. The company is looking for an Indian agent who can store large quantities of stock and has a good network in order to make an impact on the market. The scooter can be transshipped to end-users in a suitcase packing box that offers compression resistance as opposed to a traditional carton box.

This unique product that offers to resolve energy shortages and combat global warming could also be the solution to navigate through traffic snarls and congested streets during the rains.

Based on inputs by Emma Yang,
Director-Taipei World Trade Center.

Speakers That Cut Through Noise



PROBLEM

Everyday speakers—whether they're in a cellphone, TV, or radio—scatter sound waves as soon as they leave the cone. A single wave can bounce off dozens of surfaces, slamming into other signals and degrading along the way, before reaching your ear in a muddled mess. Adding to this audio chaos, most midrange TVs only emit sound from rear or downward-facing speakers. So turning them up just doesn't help. Gamers and TV obsessives often turn to soundbars and directional speakers for relief, but even those don't offer a true high-fidelity fix.

SOLUTION

HyperSound Clear speakers aim sound waves directly at a listener using a tightly focused beam. It uses ultrasonic waves, which don't disperse as quickly or easily as standard sound waves. Embedded in that signal is high-fidelity audio with zero disruption. That means a movie's epic surround sound can be directed straight at your ear—just like a laser. HyperSound speakers were designed for the hearing impaired, and like hearing aids, they must be tuned by a doctor. However, in 2014, gaming audio giant Turtle Beach merged with HyperSound's parent company, raising hopes in the gaming world that laser-focused high-fidelity will be coming to Cheetos-crusting couches one day soon.

MICHAEL NUÑEZ



Too Much Innovation

SMART PLATE, DUMB IDEA



We Americans are a health-obsessed bunch, buying niche gadgets like we para-able step trackers and sensor-filled

adhesive strips to help maintain our fitness. Now to keep our outrageous consumption habits in check, there's the SmartPlate—a \$149 Wi-Fi-connected dinner plate that automatically measures the calories in every meal. The plate is equipped with three cameras embedded within the plate's meal dividers. The cameras work with an object-recognition martphone app. Scales in each compartment determine portion sizes. The system can identify more than 400,000



different types of food. It's accurate enough to tell the difference between wheat and flour pasta, and the app offers suggestions for what to add and subtract from your meals. The American Heart Association has even partnered with the company. Yet the SmartPlate isn't dishwasher or microwave friendly, which could deter the average glutton from forking over the cash. Because as we know, a dinner plate that can't be used to nuke Hot Pockets is useless in most American homes. **LOREN GRUSH**



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A Surfboard Made By a Rocket Scientist

Edison Conner, a former SpaceX rocket scientist and co-founder of Varial Surf Technology, tried for years to create a durable surfboard from aerospace material. In his eyes, the surfboard industry was ripe for disruption. Makers had clung to one manufacturing method for more than 50 years. For strength and flexibility, they created a spine from a strand of wood (known as a stringer) and glued it into a polyurethane foam cast. The cast was sanded and wrapped in fiberglass and resin. Conner and the other engineers at Varial tried something different. They replaced the wooden stringer with an ultra-rigid foam similar to the type used in helicopter rotor blades and in rocket-propulsion systems. The foam is 30 percent stronger, with seven times the stiffness (or modulus) of conventional foam. It's also 25 percent lighter. That means surfers have a board that's easier to control and more durable.

BLAST OFF!



PEEK INSIDE

This 70x magnification of the Varial Foam microstructure reveals a tight cell structure made up of defined angles and polygonal shapes. The rigid structure of the foam makes surfboards lighter, stronger, and easier to ride.

Varial's chemists altered the polymers of the foam, producing high levels of crystallinity. The crystallized foam consists of structured, rigid latticelike polymer chains. Crystallization also makes cell walls thinner. That lets chemists pack more cells into a tighter, more-angular (or polygonal) cell structure. The structure is stronger and firmer than the looser, more-bubblelike cell structure of conventional polyurethane foam.

Aside from strength and durability, the new boards have more action (or buoyancy) in the water. "They are ultra light, which I love in smaller waves," says top pro surfer Shane Dorian, who won the Billabong Ride of the Year Award in 2015. "Ninety percent of the time, I'm surfing head-high waves or smaller, so the responsiveness of the light boards is amazing."

MARK ANDERS

Compiled by: **Kunal Gangar****Utilities Available Now!**

With Galaxy S6 supporting wireless charging, Samsung has come up with a monitor to complement the function. The SE370 not only offers good picture quality but also integrates wireless charging capability and all a user needs to do is place the device on the charging area.

Samsung SE370: TBA**Availability:** TBA for India

Find LG's G4 expensive? Well, say hello to its affordable sibling that brings a stylus and some of the features from the flagship device. The phone bears similar looks and comes with LG exclusive features like Gesture Shot, Glance View and Knock Code. The G4 Stylus also comes with laser autofocus feature for faster focusing while using the camera.

LG G4 Stylus: ₹24,990**Availability:** Out now

Utilities Available Now!

Claimed to be 2016's flagship killer, the OnePlus Two brings top of the line hardware with optimised software. The phone features an aluminum-magnesium alloy frame, jewelry-grade stainless steel accents and OnePlus' signature sandstone finish. The OnePlus Two features Snapdragon 810 SoC, 4GB RAM, 64GB internal memory along with 4G LTE support, 13MP rear-facing, 5MP wide-angle front-facing camera and 3300mAh battery.

OnePlus Two: ₹24,999
Availability: From August 11



Logitech's little noise machine has gotten louder. The X50 is deceptively loud for its size and comes in exciting colour options to complement your style. It can connect to a device via Bluetooth but there's also an auxiliary jack to connect to non-Bluetooth devices.

Logitech X50: ₹2,495
Availability: Out now



Developed closely with Google, the Pixel V1 is the first device from Lava to be a part of Google's Android One program. Being certified by Google means the phone is tested for speed and performance by the Mountain View company along with future software updates. The phone boasts a 5.5-inch HD display, 1.3GHz quad-core CPU, 2GB RAM, 32GB internal memory and a 13MP camera with improved 5P Largin lens and Blue Glass Filter.

Lava Pixel V1: ₹11,350
Availability: Out now



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Electric Revolution

Tesla has grown into an icon of the automotive world in a relatively short span of time, and that's because the Model S hits eye-watering speeds in an even shorter span of time. We drive the revolutionary electric luxury sports car.





Neck-snapping torque, zero tail-pipe emissions — actually, no tail-pipes at all — and a contemporary, elegant interior are all part of one delectable package called the Tesla Model S. While many have begun downsizing engines, lopping off cylinders and adding all kinds of blowers, Elon Musk and his team at Tesla began a few years ago what has established itself as a force to be reckoned with — the Model S.

What do people really want from a car? Luxury? Speed? Handling? Gadgets and connectivity? A big engine? If you've said 'yes' to the first few, you probably realise that the last bit isn't all that important. It's getting all of the former which matter today. Cars need to be efficient and fun. They can be hybrids as long as they consume less fuel and emit fewer pollutants. Tesla have gone one step further than everyone else. They've done the seemingly impossible — they've created a fun, luxury electric car.

The Tesla Model S is a beautiful car. It has everything one looks for in a modern automobile — definitive structure, smooth lines and curves, flared wheel-arches with haunches at the rear, making it hard to not stop and stare. It exudes a special aura and the attention to detail both on the outside and in the cabin speak volumes of the car and its creators. The interior is a mix of leather, wood and glass, with the tablet-laden centre console and panoramic roof making the cabin feel not just airy, but rather bespoke. The quality and high levels of fit-and-finish testify to the many hours of effort put into its creation.

Having been around since 2012, the Model S was initially offered with a 40-kWh battery pack. A 60-kWh option was added later, and, finally, the 85-kWh performance model we've driven here. For those with range anxiety, Tesla

Motors also began offering battery swaps. Nevertheless, the Model S is an exciting car and it can sprint to 100 km/h in a surprisingly short 5.6 seconds.

This is a 2.1-tonne car and it's planted as ever. The steering is light but reassuring and, with the Bosch electric power steering assist at work, it predictively smooths out the wheel and gives me good feedback at the same time, with even the slightest of inputs returning noticeable results.

Hard on the brakes and into the tight right-hander and the S is still composed, eager for more. The tyres squeal as I step on the gas, er, electricity on the exit and into the hairpin left. Slamming on the brakes just before the '30' speed limit sign. Once crossed, I put my foot down hard. Like being shot from a cannon, nothing could prepare me for the severity of forward movement. My head is thrown backwards neck-snappingly quick, held in place only thanks to that head-restraint. What a rush of exhilaration! The Model S is quick. It can give many a lauded petrol-powered sports car a run for their money, even put some of them to shame. That is the level of dynamic performance on offer, and without compromise elsewhere, I might add.

Tesla now have a Model S with an all-wheel-drive performance option, the P85D — D signifying dual electric motors and not 'diesel' — with a 224-PS equivalent front electric motor joining the 476-PS equivalent high-performance rear motor, allowing for a claimed 3.3-second sprint to 100 km/h, and a top speed of 250 km/h. All of this without a drop of fossil fuel involved. That should indeed raise the game further.

Tesla are on the radar, they are, with BMW and Porsche working on their own challengers in this all-electric luxury-sport arena. This is the electric revolution, and it's yours to experience today.



The Kawasaki Z250

It is a nice racy quarter-litre motorcycle that will reward the enthusiast who's looking out for a combination of grunt, handling, refinement and big bike looks.

From a distance, you could almost pass off the Z250 as a bigger bike than what it really is. After all, its look mimics the styling of much bigger siblings like the Z800 or even the Z1000. Sharp and edgy, the Kawasaki cuts a fine figure and does manage to turn heads wherever it goes. Swing a leg over the motorcycle, though, and you quickly realise that despite its big-bike look, the Z250 is actually very compact. Indeed, a tall rider might even feel mildly cramped. The relation between the smallish seat, the somewhat narrow handlebar and the rear-set foot-rests, however, does end up making for a slightly racy riding position.

The Z250 is powered by a refined liquid-cooled and fuel-injected 249-cc parallel twin with eight valves and DOHC, and transmission is via a slick shifting six-speed 'box. For a quarter-litre bike, there's plenty of performance. Wring the throttle hard and you are rewarded with brisk acceleration and quite a howl from that parallel twin engine. There's plenty of grunt at the top of the rev range but there seems to be a lack of bottom end

and mid-range. You will find yourself downshifting on several occasions to regain lost momentum after slowing down or when you need to get going to overtake the truck or bus ahead of you. Thankfully, the sweet nature of the gearbox means that shifting through the 'box – up or down – isn't a chore that it may be on a bike with a less well-crafted gearbox. Personally, I don't think that the Z250 would be ideal for touring, given its nature; however, it can cruise quite comfortably at 110-120 km/h. This is important since a vast majority of Indian enthusiast motorcyclists end up touring our ample countryside. Where the Z250 comes into its own is in the handling department. There's absolutely no area where you will be robbed of confidence where the bike's handling is concerned. It holds its line and feels confident at all times, through every twist, turn or straight. Great for a novice who's learning to ride fast.

The suspension set-up, though, is on the stiffer side of life, which is probably a boon on well-surfaced twisties when you want to have some fun or on a smooth

track. However, on our potholed and bump-ridden Indian roads it tends to tire you out. It's not jarring but you do feel every road irregularity under its 17-inch alloy wheels.

There is plenty of bite and progression for the rider to be able to haul the bike down from triple-digit velocities without fuss. And on most days the brakes are more than enough as a match for the motorcycle. Unfortunately, the bike does not get the benefit of ABS, which we think is a must for a motorcycle of this nature. Overall, at the end of the day, the Kawasaki Z250 is a well-sorted motorcycle. Consequently, the Z250 has the performance to match its looks, is refined and is a very able handler. However, at nearly Rs 3.5 lakh on-road in Pune, it's an expensive motorcycle. Now, Kawasaki, I'm sure, have their strategy (and, therefore, pricing) sorted out but one mustn't forget that the market, the consumer and his demands have changed quite a bit. As a result, for that kind of money you could have something else that's as much fun but with money still to spare.

EDITED BY *Breanna Draxler & Jen Schwartz*

Next



Lightning is incredibly powerful. One strike can contain 1,500 megajoules of energy—enough to power a 100-watt lightbulb for six months. But scientists know only the basics of how it works. Maher A. Dayeh, a heliophysicist at the Southwest Research Institute in San Antonio, aims to change that. In July 2014, his team triggered a bolt (shown here) by shooting a rocket trailing copper wire into a storm cloud. Fifteen microphones captured the sound waves created as heated air around the bolt expanded and then compressed. The result? The first-ever acoustic image of thunder. From it, researchers can infer how much energy went into forming the bolt, and how much it radiated as sound. Lightning is violent, Dayeh says. "Prediction and protection are almost impossible if we don't understand the process in the first place." **RACHEL FOBAR**

3.9

Estimated number of times, in millions, lightning strikes Earth every day, according to NASA's Marshall Space Flight Center

TAKING THE GUESSWORK OUT OF FOOD

Between the reports of *E. coli*-tainted spinach and *Listeria*-laden ice cream, it's easy to become paranoid about what to eat. And rightly so: One in six Americans will get a food-borne illness this year. But a number of new and soon-to-exist food-monitoring technologies can help keep your fridge contaminant-free, flag when something should be tossed, and tell you exactly what's on your plate. **HEATHER HANSMAN**



1 MILK
Scientists at Peking University in Beijing created gold nanorod tags to put on food packages. They're designed to deteriorate at the same rate as what's inside. A color change will indicate if a jug of milk has gone bad without having to take a whiff (or worse, a swig). "In principle, the tag can be used for any product that deteriorates over time and is packaged air-tightly: beverages, medicines, vaccines, and more," researcher Chao Zhang says.

2 MEAT
Expiration dates are static; people often throw away food that's still good—or eat food that's gone bad. Chemists at MIT created a thin sensor that can be put inside meat packaging. Its metal-lined carbon nanotubes carry a current that drops when it encounters amines, chemicals produced by decaying meat.

3 FISH
The FDA limit for mercury in tuna is 1 part per million. But levels vary from fish to fish. While most tuna companies sample a few fish per catch, Safe Catch made a quick test to biopsy every tuna at the dock, accurate to 0.1 ppm. "We're not OK using anyone's average," says Bryan Boches, Safe Catch co-founder.

4 OLIVE OIL
A 2012 study found that 60 percent of olive oil sold to restaurants in California as "extra virgin" didn't meet USDA quality standards. Researchers at the University of California at Davis developed an enzyme-based electrochemical biosensor that ferrets out aldehydes indicative of less-pure oil.

5 FRUITS AND VEGETABLES
When food-borne illness breaks out, it can take months to follow the bug back to the source. A food-safe spray called DNATrax, developed at Lawrence Livermore National Lab, uses DNA extracted from plants to create a traceable molecular barcode that's unique to fresh produce's farm of origin.

33

Percentage of fish sold in U.S. stores and restaurants that were mislabeled, according to a 2013 Oceana study

A Food Label Just for You

Frustrated by one-size-fits-all nutrition facts, designers at New York University decided to intervene. "We want food labels for consumers rather than a compromise between government, food lobbies, and big food companies," says Sam Slover. Their app, called Sage, uses info like your weight and activity level to create personalized labels for food. If you've got a peanut allergy, it can flag risky products. If you splurge on cheesecake, it'll tell you how many minutes you'll have to spend on the elliptical to burn it off.



Vint Cerf

On the Interplanetary Internet



The Internet has changed a lot over its 30-something years. That terrible dial-up noise is gone; the Ethernet cord has been cut; Tinder happened. What's next? If anyone knows, it's Vint Cerf, Google's vice president and chief Internet evangelist. He is

considered a "father of the Internet" for developing the protocols that run it: breaking information into packets, sending them into cyberspace, and reassembling them onto your screen. Cerf has watched his baby grow up and get smarter. Now he's envisioning how it will mature in the coming decades.

50

Number of devices, in billions, Cisco Systems Inc. expects to be connected to the Internet by 2020

“

When we turned on the Internet in 1983, having a powerful computer in your pocket was science fiction. But the Internet has evolved beyond even cellphones to encompass smart objects that talk to each other and to you. Those devices—called the Internet of Things—now need standard protocols that allow connected products from different companies to work as an ensemble.

Soon cars, buildings, cities, and people will have sensors and software that track resources, respond to crime, or take constant vital signs. In that environment, machine learning will become increasingly important—not insane robots but systems much smarter than today's Google searches.

Once we've connected everything to everything else, safety and privacy will be big challenges. It's impossible to stop abuse, but we have to be able to detect it. We need to develop better security and authentication technology, as well as better international agreements to prosecute cross-country cybercrimes.

The Internet, though, will extend beyond political borders, and even beyond Earth. A prototype Interplanetary Internet already stretches between our planet and the International Space Station. Astronauts use it to communicate with Earth. The Interplanetary Internet will evolve and expand as old spacecraft become nodes in its backbone, helping pass along signals.

To handle the delays and disruptions that occur in space, we need robust protocols. I helped develop the new "bundle protocol," which assumes the link will break occasionally. When that happens, it stores the packets of data and waits to send them until the connection becomes secure again. The United Nations is in the process of adopting it as the standard that will support manned and robotic exploration into deep space.

We initially designed the Internet to be a network of networks that could expand over time. And so it has. And so it will." **AS TOLD TO SARAH SCOLES**

"There are only about 3 billion people online. It's not everybody in the world, so there's a lot of work to be done."

NEXT

Concepts & Prototypes



SPECS

Combat Range 1480 km, depending on payload

Payload Four crew and up to 14 troops, or more than 5,443 kg of cargo

Speed 280 knots, or 514.9 km per hour



THE MOST VERSATILE AIRCRAFT IN THE SKY



Future conflicts will favor faster, nimbler military forces—think precision strikes and special ops. “The military needs assets that allow

them to project their combat power more rapidly,” says Keith Flail, a program director at Bell Helicopter. It needs an aircraft that can hover for tactical maneuvers but also conquer the “tyranny of distance.”

The V-280 Valor could do just that. Its tilt-rotor design allows the craft to take off and land vertically, like a helicopter, or pitch its rotors forward to fly horizontally, like a turboprop plane. It stands to be safer and more agile than its clunky cousin, the V-22 Osprey. And with



1

STREAMLINED NACELLES

Unlike the larger, less-agile V-22 Osprey, the V-280's rotors tilt while its engines and gear boxes remain stationary. This eliminates moving parts, and keeps the engine housing out of the way to make entering and exiting the aircraft easier and safer.

2

CARBON ROTOR BLADES

The first-ever all-carbon tilt-rotor blades make the V-280 light and maneuverable, particularly when operating at low speeds. They also boost stability in crosswinds and can reduce propeller downwash, which affects cargo loads tethered to the aircraft's belly.

3

FLY-BY-WIRE CONTROLS

In conventional helicopters, the pilot spends a good deal of effort simply keeping the aircraft stable. The V-280's advanced fly-by-wire controls allow flight computers to do much of that work, which is especially useful when transitioning between its two flight modes.

4

STRAIGHT WING

In contrast to swept wings, which form the V-shape of most jets' profiles, Bell's engineers designed a straight wing with a single drive shaft that runs its length. This enables the craft to operate both rotors via a single engine if one loses power.

5

SITUATIONAL AWARENESS

A head-up display on the visor of the pilot's helmet stitches together footage from six cameras on the outside of the craft. This allows the pilot to essentially see through the walls to what's beneath, beside, or behind the plane. As Flail describes it: "It's kind of like flying in Wonder Woman's jet."

6

MODULAR PAYLOAD BAY

The payload bay could hold weapons systems that turn the V-280 into a fast-moving gunship. Close air support weapons could be extended from the bay doors during combat and articulate back into the aircraft during cruise flight to reduce drag.

“Our nation and our service members should never have to fight a fair fight.”

—KEITH FLAIL, DIRECTOR OF THE FUTURE VERTICAL LIFT PROGRAM AT BELL HELICOPTER

twice the speed and combat range of the Army's current workhorse, the Black Hawk helicopter, the V-280 could vastly extend the reach of U.S. ground forces.

Bell Helicopter's design is vying

for the top spot in the Army's Future Vertical Lift program, which aims to develop a family of next-generation rotorcraft. If chosen, the V-280, or something like it, could be navigating the skies by 2030. CLAY DILLOW

Lab-Grown Diamonds to Keep Electronics Cool

↓

A clear, sparkling diamond is rare. That's part of its appeal. Those mined today formed billions of years ago. But a new method can grow gem-quality diamonds on demand in just three months. They're identical to their natural counterparts and cost 30 to 40 percent less. That's promising for anyone in the market for an engagement ring. And it bodes well for the future of electronics too. **REBECCA HARRINGTON**



5

In March, IIA opened the world's largest diamond-growing facility in Singapore. It's capable of cranking out more than 300,000 carats a year, using half the energy of diamond mining. Plus it has far less environmental impact. To the naked eye, the diamonds are indistinguishable from natural ones. But they'll still be a tough sell for jewelry, where lab-grown make up less than 1 percent of the market. "They're seen as inauthentic, no matter that they are objectively identical," explains Ravi Dhar, director of the Center for Customer Insights at Yale University.

72

Global diamond jewelry sales, in billions of dollars, per year

6

Diamond's unsurpassed thermal conductivity makes it an ideal heat sink for electronics. It transfers about twice the heat and can carry more current than the silicon usually used in semiconductors. IIA is working to grow diamond plates that will enable smaller, more powerful devices that don't overheat. "It will take time," says physicist Devi Shanker Misra, who invented IIA's technique, "but I hope that it will replace silicon."

1

Global demand for diamonds is currently on the rise, thanks in part to a growing middle class in countries such as India and China. But it's been a decade since a large diamond mine has been discovered. By 2019, demand is projected to outstrip supply by 5 to 6 percent.

2

Luckily, diamonds can also be made in a lab. In the 1950s, scientists first created diamonds by replicating the intense heat and pressure that forms them underground. The stones tend to be discolored and small (in some cases just a powder), but they retain a natural diamond's defining properties.

3

Diamond is one of the hardest known materials. It can withstand high levels of radiation and doesn't trigger an immune response. This makes it useful in construction, nuclear engineering, and medicine. In 2013, industry used about 680 tonnes of diamond, 99 percent of which were lab-grown.

4

To make purer gems, diamond-grower IIA Technologies refined a process called chemical vapor deposition. In a vacuum chamber, they shower a fingernail-thin diamond "seed" with microwave rays and methane and hydrogen gases. These build up layers of carbon bonds.

"If anyone says they can tell the difference without a machine, they're lying."

—ARIEL BARUCH, JEWELER AT DIAMONDS BY ISRAEL STANDARD INC., WHICH SELLS LAB-GROWN DIAMONDS

Robot Pets Have a Leg Up on Fido



Humans have been bonding with domestic animals for tens of thousands of years, but Jean-Loup Rault, an animal scientist at the University of Melbourne, thinks new companions are coming: robot pets. Just as digital technologies have altered how we interact with each other, they could soon do the same for us and animals.

This may not sit well with pet-lovers. A plastic dog is hardly as cuddly as a Pomeranian. But Rault argues the robot variety has a lot going for it: "You don't have to feed it; you don't have to walk it; it won't make a mess in your house; and you can go on holidays without feeling guilty." Plus mechanical animals could open up pet ownership to people with allergies, mobility issues, or tiny apartments.

The biggest selling point might be that robot pets combine the utility of a machine with the companionship of an animal. Dan Goldman, who works with biomechanical robots at the Georgia Institute of Technology, spitballs what one might look like: "It'll be a dog that can read your emotions and respond. It'll be a snake that can slither under your bed to find toys." One day we might even be able to transfer a robot pet's memory to an upgraded model to make it a lifelong companion.

That's convincing on a practical level, but it doesn't address whether humans can actually bond with machines. Studies suggest we can: When companion robots like

Paro, the sensor-studded interactive seal, have been given to nursing-home residents, they can improve moods, combat loneliness, and increase

social engagement. "As humans, we're eager to bond with things," says Bill Smart, who studies human-robot interactions at Oregon State University. "People give their cars names. Kids give their stuffed animals backstories." So too with robots. When Sony shut down the last tech clinic for its discontinued dog Aibo in March 2014, owners in Japan held funerals.

In the end, what might hold people back from adopting robot pets could be as simple as their frame of reference. For those who grew up with living, breathing, slobbering pets, the mechanical kind might not do. Neither Rault nor Smart wants one. But for kids who constantly engage with smart technology, extending that connection to a robot dog or dino just might be the next logical step. **BREANNA DRAXLER**

A BRIEF HISTORY OF ROBOPETS

1996 Tamagotchi
1998 Furby
1999 Aibo
2001 Paro
2002 Roomba
2005 iDog
2006 Pleo
2014 MiP
2015 Ringo



"At some level you know it's a robot. But as you interact with it, you'll probably find yourself doing things that you'd do with animals." —BILL SMART, ROBOTICIST AT OREGON STATE UNIVERSITY



World View Experience says
it will take passengers to the
stratosphere by 2017.

Wish You Were Here

You don't need a rocket to experience space.
There's a slower, gentler trip in the
works—and it comes with a cocktail.

By Kalee Thompson



A helium-filled balloon will carry Zero2Infinity's tourist pod to 35 km above Earth.

When Alan Eustace lifted off into space from the New Mexico desert this past October, it was with a quiet whoosh, and a slight jostle of his harness. The 57-year-old computer scientist from Google—outfitted in a 418-kg pressurized space suit—dangled solo from a polyethylene balloon as thin as a dry-cleaning bag. As the balloon rose steadily into the air, the small bubble of helium inside began to expand, and with each kilometer the balloon changed shape. At first it undulated skyward, limp and oblong, like a jellyfish. Then it grew into a soft, bulbous teardrop. Finally, as Eustace neared his destination, 40 km above the planet's surface, it became perfectly firm and rounded, a shimmering object the size of a football stadium. Above him spanned the blackness of space. Beneath him lay what has long drawn humans to these heights: the soul-altering view of the curvature of Earth.

To most, Eustace's flight seemed the antithesis of space travel, which since the dawn of the space age has been synonymous with the fiery roar of a rocket. The first private companies racing to take paying customers to the edge of space—Virgin Galactic, XCOR Aerospace, and Blue Origin—promise the kind of thrill ride experienced by astronauts. But there's an alternate space race taking shape, one whose selling point is slow and serene. A handful of startups are rushing to pioneer tourist trips to the stratosphere beneath enormous balloons. "Balloons are a beautiful mechanism for taking off," Eustace says. "You're perfectly balanced; it's perfectly quiet; there's no vibration as you're going up." Once at altitude, passengers will drift with the winds as they peer from the comfort of

a pressurized capsule. After a few hours, they will glide back to Earth beneath a wing-shaped parafoil.

For one company, Eustace's StratEx mission was proof of principle—a "one-man version" of stratospheric balloon tourism, says Taber MacCallum. He and his partner, Jane Poynter, headed Paragon Space Development Corporation, which managed Eustace's flight plan and built his life-support system. The couple then started World View Experience, a Tucson, Arizona, operation that intends to be the first to take customers to 30480 meters, or 30.5 km, for \$75,000 a head. They project the maiden flight will take place by 2017.

Zero2Infinity in Barcelona and Chinese startup Space Vision also anticipate flying passengers in the next few years. They are

**"YOU CAN
TAKE YOUR
PARENTS
AND
CHILDREN.
IT'S GOING
TO BE THE
ULTIMATE
FACEBOOK
STATUS
UPDATE:
THE ENTIRE
FAMILY IN
SPACE."**

selling tickets for about \$125,000 and \$80,000, respectively. The fees are steep, but not when compared with \$250,000 for a seat on Virgin Galactic's suborbital spaceplane, or the \$50 million broker Space Adventures charges for a weeklong jaunt to the International Space Station.

Altogether, balloons could offer a more inclusive form of space tourism. "It's a very slow, gentle ride up and a slow, gentle ride back, and you get to be up there for hours," MacCallum says. Without the gravitational forces of takeoff and landing, the flight comes with minimal health restrictions. Motion sickness is unlikely to be an issue. Couples might get married in near-space, or celebrate a grandparent's birthday. World View is already taking \$7,500 deposits to secure seats on future flights. "We've had families sign up and buy the whole capsule," MacCallum says. "You can take your parents and children. It's going to be the ultimate Facebook status update: the entire family in space."

In 2002, two years before Scaled Composites claimed the \$10 million Ansari XPRIZE for private spaceflight, Zero2Infinity's founder, José Mariano López-Urdiales, wrote a paper for grad school entitled "The Role of Balloons in the Future Development of Space Tourism." In it, he calculated stratospheric ballooning could be a \$10 billion-a-year industry. Much of the technology required to send tourists to such altitudes—the balloons, the helium fuel, the pressurized capsules—had been well proved, López-Urdiales noted. It's also relatively affordable and easy to procure.

Rocket flight, in contrast, is both costly and difficult. The public got a stark reminder of that this past fall, when Virgin Galactic's *SpaceShipTwo* exploded over the Mojave Desert, killing a test pilot. "When you light a rocket, 10,000 things can happen, and only one of them is good," says Michael López-Alegria, a former NASA astronaut who recently signed on to advise

Zero2Infinity. With balloons, he says, "you're not going as fast, you're not going as high, you're not putting as much energy into the system."

Whereas Virgin Galactic plans to soar to nearly 1,00,589 meters—just past the 99.75-km mark widely considered the threshold of space—balloons will top out at just over 30,480 meters. The difference is not as significant as it might seem. "At that altitude, you've got 99 percent of the atmosphere underneath you," says former space-shuttle commander Mark Kelly, now the director of flight operations for World View. "You're essentially in a vacuum. You're in the blackness of space." He agrees with López-Alegria that balloons pose less risk. "If you can take the complexity out of getting people to that vantage point," he says, "at least theoretically you can do it a lot safer."

The straightforward nature of balloons has long been appealing. In fact, they powered the very first space race. In 1931, a balloon lifted Auguste Piccard and Paul Kipfer to the stratosphere in a pressurized capsule, a feat described in the August 1931 issue of *Popular Science* as an "adventure [that] surpasses fiction." As we wrote then: "Seventeen hours later, after being given up for dead, they returned safely from an altitude of more than 14,849 meters, almost 16 km, shattering every aircraft altitude record." New records continued to be set and broken through the 1950s. And then in 1960, U.S. Air Force Capt. Joe Kittinger rose to 31,333 meters. His record stood for 52 years—until October 2012, when Austrian skydiver Felix Baumgartner ascended to 39,044 meters. Eustace passed Baumgartner's milestone two years later, reaching 41,419 meters.

Like Kittinger and Baumgartner before him, Eustace floated briefly in the stratosphere, taking in a view he calls "marvelous." As he remembers now, "It's beautiful watching how the light diffuses through the different levels of the atmosphere." And then Eustace released his balloon and fell back to Earth

protected by only his space suit. His body reached 1,322 km per hour, exceeding the speed of sound, before the atmosphere thickened and a parachute deployed to slow his descent. To succeed at ushering in a new form of balloon-based tourism, companies will have to figure out a way to get customers not only up, but also down.

A balloon ride to the stratosphere will be a three-part act: the launch, the pleasant cruise at altitude, and the trip back to Earth. The first part should be straightforward. For its commercial flights, World View plans to use a balloon that's more than 122 meters in diameter—the same size as the one that carried Eustace. (Though it will be towing a 4,082-kg tourist capsule, the balloon doesn't need to ascend as high.) Because of the StratEx mission, World View's team has practice launching it.

Zero2Infinity has been launching unmanned balloons as a test for two different business ventures: stratospheric tourism and a commercial satellite delivery system. It's also designed a doughnut-shaped craft that it plans to adapt for both applications. The version that will carry tourists, called a Bloon, will be big enough to hold two pilots and four passengers. The company has so far built a prototype half that size and used it to send a small humanoid robot to near-space. ("In the old days it would have been a



↑ Passengers in World View's capsule (here, a mock-up) will have Internet access for uploading photos.

THE CAPSULE WILL HAVE A BAR AND A BATHROOM, AND THE CREW WILL DOUBLE AS BARTENDERS AND TOUR GUIDES.

dog or a monkey," López-Urdiales says.) Equipped with cameras and sensors, the robot helped the engineers at Zero2Infinity understand the passenger experience. When the robot looked through the windows, which ring the outside wall, reflections marred the view. As a result, the window's position will likely change, López-Urdiales says.

World View envisions an oblong capsule with viewing ports on each side. About the size of a small Winnebago, it will have seats for six passengers, a pilot, and a crew member. Passengers will need to be buckled in for liftoff and landing, but most of the ride will be a casual sail, like a skiff gliding across the surface of a lake in a light breeze. Although winds at 30,480 meters can reach 209 km per hour, the high speed won't be perceptible. That's because Earth, which provides the only reference point, will appear to barely move. The capsule will have a bar and a bathroom, MacCallum says, and the crew will double as bartenders and tour guides.

Both MacCallum and López-Urdiales agree that balloon tourism should provide a shirtsleeve environment throughout the flight. "The goal is to have no training, no space suits," MacCallum says. "This will be very similar to a commercial-airline flight, where you're given a briefing and off you go." But outside the pressurized capsule, the environment is lethal. Exposure would mean near-instant death. For that reason, the companies will have to decide how to balance comfort with

safety in the event of an emergency.

"At the very least the pilot should be wearing a space suit," says Art Thompson, whose aerospace company, Sage Cheshire, built the pressurized capsule that carried Baumgartner to the stratosphere. "If you have an issue with the craft, you want the pilot to be able to be in control." The smartest strategy, Thompson says, might be to convince tourists to wear suits too. Of course, space suits require training, and looking like an astronaut might not have as much appeal as being able to easily sip a cocktail or hold your kid's hand at 30,480 meters. At this point, the companies just seem to be banking on their ability to get the capsule down if a problem is detected—no awkward garments or free-fall skills required.

The third phase of the journey, the return, will be the most difficult. So World View is now heavily focused on refining the parafoils that will deliver the capsules to Earth. "We want to have enough cross-range to be able to fly to an airstrip and gently land in a predetermined place," MacCallum says. "Doing that from 30,480 meters has never been done." Because the air at that altitude is so thin, many doubted it was possible. But the company has now flown unmanned parafoils from 30,480 meters three times, each with a payload of about 45.36 kg. This summer they plan to step it up by a factor of 10, testing the GPS-guided



↑ Physicist Auguste Piccard prepares to make his second balloon trip to the stratosphere in 1932.

The Ride of Your Life

Space tourism will offer different experiences, depending on the cost of a ticket—and your taste for adventure. Here are two.

STRATOSPHERIC BALLOON

CARRIER:
World View
Experience

COST:
\$75,000



1 You board the capsule a couple of hours before dawn. The monstrous polyethylene balloon that will lift you into the stratosphere towers in the air above. You choose a seat, but it doesn't really matter—they all swivel for a 360-degree view. After a five-minute briefing from the pilot, a former astronaut, the craft begins to rise.

2 The ascent is slow and steady, averaging about 18 kmph. You barely feel it. As the helium inside the balloon expands, the shape transforms from a long, thin teardrop into a taut, rounded object. After an hour and a half, the balloon reaches 30,480 meters. You're free to walk around, use the restroom, or have a cocktail.

3 The craft drifts at this altitude. Its movement is gentle; the pilots refer to it as "sailing." They point out constellations and planets. Soon, the sunrise

begins, illuminating the winding scar of the Grand Canyon 30.5 km below. Your pilot describes his own first experience with the so-called overview effect, the emotional shift in perspective that comes with gazing down at Earth. You pull out your phone and snap a picture, a selfie from the stratosphere.

4 After two hours, the pilot vents helium from the balloon to begin a descent. He then sets the balloon free, leaving the capsule hanging from a 30.5-meter-wide

parasail. It begins a directed glide. The wind pushed the balloon several hundred kilometers, and the parafoil will make up most of that distance on the return. The pilot's attention is focused on flying—this is the part of the trip he has trained for. The sensation is similar to being in a small, perfectly silent airplane. The swooping descent takes less than an hour, delivering you to an airfield four to five hours after you lifted off.

ROCKET-POWERED PLANE

CARRIER:
XCOR
Aerospace

COST:
\$100,000

1 You're secured into the passenger seat of the Lynx suborbital spaceplane, seconds from takeoff. You've passed your medical examination and spent two days training, learning tricks of the trade like shallow breathing to handle G-forces. Though the cabin is pressurized, you're wearing a pressure suit as

backup. Air traffic control speaks through the radio in your helmet. "Cleared for takeoff. Three...two...one. Ignition."

2 The four rocket boosters in the plane's tail ignite, and the spacecraft roars off the runway. In 60 seconds you're at supersonic speeds, although from inside the cockpit you can't really tell. All you know is that

you're going fast. You tilt back as the Lynx's nose rises, hurtling up through the atmosphere at an 75-degree angle. The altimeter clicks upward toward 1,00,584 meters, and the surface of Earth fades away.

3 Then, suddenly, it's just you, the pilot, and the blackness of space. Gravity doesn't seem to tug at your arms anymore, and you can see far beyond the curvature of Earth. You're weightless. The pilot adjusts the boosters to keep you on track, but this is your time to take in the view.


4 After about five minutes, you begin to descend. The force of gravity returns, stronger than before. Re-entry is swift and hard. At its greatest, you feel the pressure of four times gravity's pull. The force lessens as the Lynx grips the atmosphere, and soon you're at cruising altitude. The spacecraft feels more like a commercial plane now, and the landing gear lowers as you make a final approach. After your 30-minute ride you touch down, back where you started.

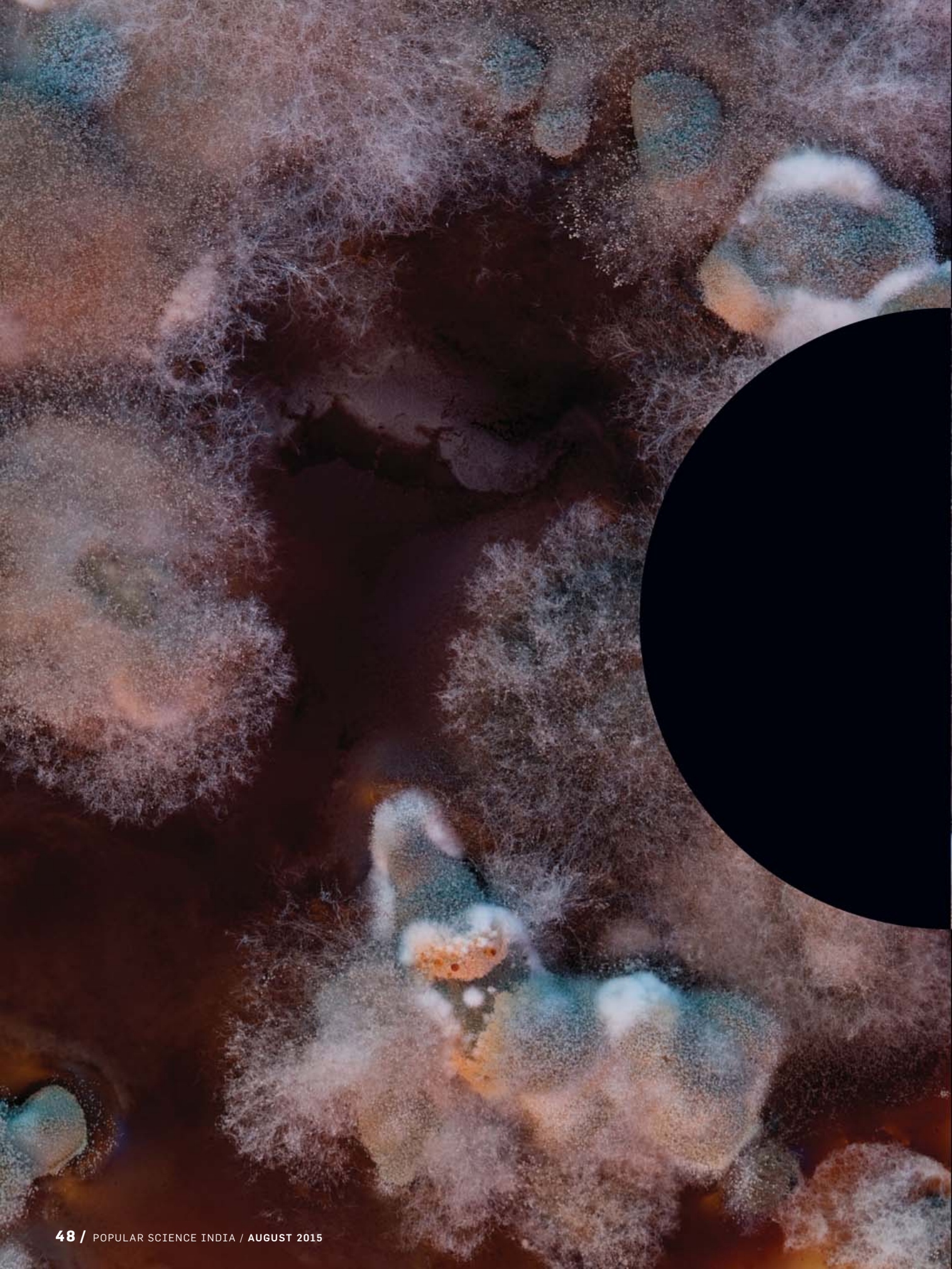


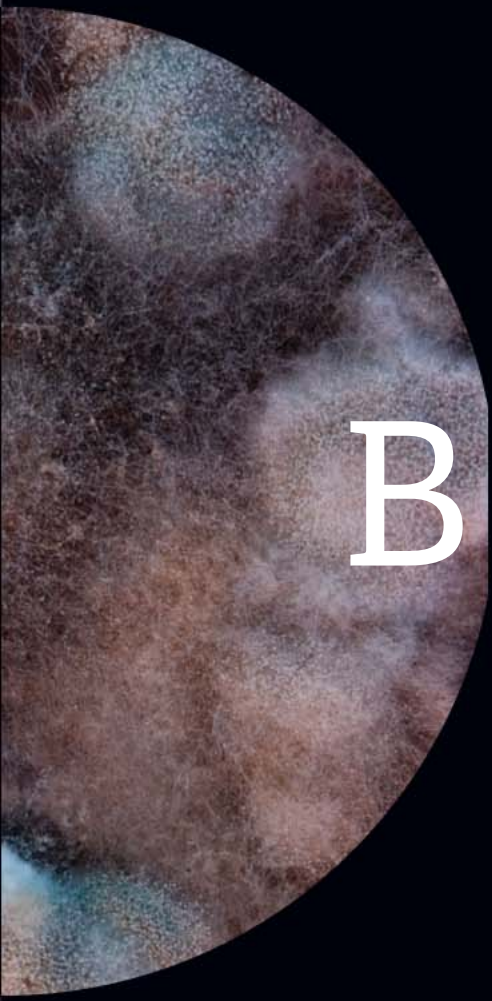
system with a 454-kg payload over the southwestern United States. "Assuming all that goes well, by the end of this year we'll be at full-scale flight with a 4,082-kg capsule and commensurately large parafoil," MacCallum says.

One focus of Zero2Infinity's upcoming flights, also scheduled for this year, will be to test the high-speed telemetry link that will beam live video down from the capsule. Another arm of the company focuses on developing huge parafoils that could act as rescue systems for traditional aircraft. While they would be much larger than the ones eventually used for tourist capsules, having two applications for the technology accelerates the development while reducing the risk and cost, López-Urdiales says.

During tourist trips, the parafoils will be guided at least partially by pilots, and so both companies will need to conduct manned test flights. Some of those test pilots will likely be former NASA astronauts. Kelly says that people who have flown the space shuttle, like him, won't be starting from scratch. The shuttle was also a glider that made an unpowered descent. Similar to a parafoil and a capsule, it encountered a lot of drag for the amount of lift it could create. To train, Kelly will spend time this summer jumping out of airplanes and learning to fly a small parafoil. Though he's in charge of assembling a team of World View pilots, he expects that he'll complete at least some of the early manned test flights himself, as well as serve as pilot on the first commercial trip to the stratosphere.

The simplicity of World View's vision—at least compared with rocket flight—is what attracted Kelly to the project, he says. Potential tourists will likewise be drawn for the same reason, in hopes of experiencing the same payoff. Before he went to space for the first time, Kelly was sure the most remarkable thing would be floating in zero gravity. "That wasn't the case," he says now. "The biggest take-away is looking at the planet with your own eyes—a round ball just floating there in the cosmos." 





WE LIVE IN FEAR OF
THE MICROBES
THAT INHABIT
OUR HOMES AND
BUILDINGS.
BUT OUR HEALTH
MAY DEPEND
ON PRESERVING
THEIRS.

Bugged

BY RINKU PATEL

SOMEONE ONCE TOLD ME THAT A PRAYING MANTIS IN YOUR HOME BRINGS LUCK AND GOOD HEALTH

As for the one sitting on my kitchen countertop in Oakland, California, well, Jonathan Eisen certainly likes it. “That’s cool,” says the University of California at Davis microbiologist, lifting the tiny aluminum toy—with huge eyes and delicate clawlike front legs—off the cold marble. He sets it down only when something even smaller, a fruit fly, buzzes past. “Look,” he says admiringly, head cocked to my ceiling, “you have *drosophila*.”

Eisen is a tall guy in his 40s with a mountain-man beard, and he has shown up at my home wearing a T-shirt with sparkly-pink block lettering that reads: “Ask me about fecal transplants.” He’s a firm believer that human health depends on bugs—not the six-legged variety, but the microbes that populate our guts and the environments in which we live, work, and play. Eisen explains that every time I open my door, a blast of air that has woven through the surrounding tree canopy carries microbes into my house—as do Amazon packages, pets, and muddy feet.

He’s musing about my oak trees when the forced-air heating clicks on. The furrows in his brow deepen. Hot, dry air shooting through a sealed house kills germs, he tells me. In fact, my whole house makes him deeply uncomfortable. It was extensively remodeled this past summer with antimicrobial fixtures, floors, and walls—now standard in many renovations. Eisen compares this practice to the overuse of antibiotics in medicine: Wipe out the natural balance of good bugs, and you might not like the organisms that survive.

A mounting body of research has shown the importance of the microbes that live inside us, and scientists have been slowly cataloguing species that live outside



Drugs designed to wipe out microbes have instead created superbugs, such as methicillin-resistant *Staphylococcus aureus* (MRSA), found in hospitals.

“Have you seen germ-free mice? They are seriously messed-up animals.”

in nature. But little is known about the microbial ecosystem that surrounds us indoors, where we spend about 90 percent of our time. Recently a group of scientists, loosely connected through the Microbiology of the Built Environment Network that Eisen founded, has begun to probe it. The White House Office of Science and Technology Policy is looking into forming a national initiative to spur further research. Once we know what organisms we live with, we can begin to determine how we rely on them—and then we can tackle this question: To what extent do we need to stop protecting people from germs and instead protect germs from people?

I lead Eisen up a stairwell slathered in antimicrobial paint, and into a study with carpet treated with stain and odor guard. “You know that’s bad, right?” he asks. Then we pop into the bathroom. Eisen stares intensely at the tankless toilet. It appears to levitate off the floor like an antimicrobial spaceship. When I ask if he wants to step outside for fresh air, he looks relieved.

CHARLES DARWIN, in *On the Origin of Species*, charts evolution through the Tree of Life. Its branches and roots lift some species toward fecundity while knocking others down to extinction. But Darwin’s tree didn’t include microbes, perhaps the most successful life-forms of all. They make up roughly 60 percent of Earth’s biomass. There are more microbes in a teaspoon of soil than there are humans in the world.

By some measures, even we are more microbe than mammal. The trillions of microorganisms we harbor in our bodies, collectively known as our microbiome, outnumber human cells 10-to-1. Altogether, they weigh up to twice as much as the human brain, existing as a sort of sixth human superorganism whose function is linked to digesting our meals, preventing infection, and possibly even influencing our emotions and moods. Studies that describe new and essential roles for our microbiome are

published almost daily. The reason for its breath-taking range is simple: Our germs have evolved with us.

Microbes appear to have prospered by making themselves incredibly useful, and we've gladly given up space in exchange for the vitamins, digestive enzymes, and metabolites they provide. And so the discovery that the urban gut harbors up to 40 percent less microbial diversity than that of indigenous people living in a remote jungle concerns scientists. These "missing microbes," they say, may have been decimated by several decades of industrialized foods, which limited our diets, and antibiotic use, which extended our lives at the expense of theirs.

Eisen offers another explanation for why our internal real estate might be in subprime condition: The microbiome within us depends upon the microbiome that surrounds us. "Have you seen germ-free mice?" he asks me. "They are seriously messed-up animals." Delivered by cesarean section and raised in sterile chambers, these rodents have inflamed lungs and colons, like those seen in asthma and colitis. They're also prone to haywire immunity and weird social tics.

Until relatively recently, sterile chambers weren't our environments either. "We didn't evolve in closed rooms," says Maria Gloria Dominguez-Bello, a microbiologist at New York University who led the indigenous microbiome study. "We evolved in nature." Big families lived together on farms and in tenements, not exactly temples of hygiene. Livestock loped in the streets. Infectious disease rippled through cities. Roofs leaked. Sewers overflowed. Windows opened. But with modernization, we sealed ourselves away. In other words, we parted ways with the microbes that evolved with us. By redesigning our buildings, we redesigned ourselves.

SOFT OF HEART and loud of mouth, Eisen enjoys a good jab. When I first met him at a Thai restaurant in Davis, he lifted up his shirt and stabbed himself with an insulin syringe. I flinched, but he grinned. "When I was a kid, I did this to freak people out," he said. Now, he's illustrating how his work in the field of microbiology is personal. Eisen has type 1 diabetes, an autoimmune disease linked to, among other things, changes in the microbiome.

To understand how seriously Eisen takes his position as the defender of microbial diversity, it's useful to know where he got his career start: in an undergraduate internship at the D.C. Public Defender Service. It fostered a lifelong ardor for justice and an impulse to, whenever possible, stick it to the bullies. He argues that microbial communities—whether in our bodies or in buildings—function as complex ecosystems, not unlike tropical rainforests. "That doesn't mean microbes don't kill some people and make others sick," he says. "But if you're afraid of a tiger, you don't clear-cut the rainforest. Well, you do in some cases, but that's crazy."

Until last year, Eisen was a member of the Forum on Microbial Threats. (He quit, saying both beneficial microbes and female scientists were underrepresented.)

“Microbes kill some people and make others sick. But if you’re afraid of a tiger, you don’t clear-cut the rainforest.”

At the time the National Academy of Sciences first convened the forum, the prevailing narrative was that microbes were an enemy of public health and we were at war with them. The approach backfired: Germs adapt to whatever drugs are thrown at them, swapping genes with neighbors to accrue antibiotic resistance. The rise of superbugs, coupled with growing awareness of the human microbiome, has led many scientists, including the forum, to rethink the merits of germ warfare.

Eisen takes a bite of stir-fry and suggests we ditch the word pathogen altogether. "Sometimes germs are good, sometimes they're bad," he says, sounding unusually Yoda-like. "Nothing is good or bad all the time."

As someone who has spent 20 years studying microbial evolution, Eisen is in a good position to explain the paradigm shift. In 2007 he helped launch a "genomic encyclopedia" of microbes—a splashy debut whose biggest point was all of the blank pages: We have no idea who the vast majority of our microbial neighbors are.

That hasn't stopped us from trying to kick them out. There are now thousands of antimicrobial products on the market, which range from clothing to cutting boards. One industry report forecasts that the \$1.9 billion coating market alone will more than double in 2020. Rolf Halden, an Arizona State University environmental engineer, says the marketing preys on consumers' fears. "There's ample evidence we use too many antimicrobials," he says, "and without judgment."

Halden has found that triclosan, a common antimicrobial, makes its way from products like hand soap into sewage, where it breeds antibiotic resistance. Studies have also detected high levels of triclosan in house dust. One found it counterintuitively helps *Staphylococcus*—a common source of infection—adhere to plastic and glass surfaces. What we don't know is how it or other antimicrobials affect the organisms that might actually help us.

This topic makes Eisen visibly agitated. He waves his fist like a trial lawyer itching to clock opposing counsel. He brings up a company hawking a new indoor sanitation technology on Twitter—a 24-hour, Purell-like system that purportedly kills everything, including ebola. It's an indiscriminate weapon in the old war. Struggling for composure, he says: "That doesn't sound good."

IN ORDER TO UNDERSTAND what happens when a built environment's microbial ecosystem is wiped out, scientists have begun to study the most sterile structures on Earth—and off. For astronauts, the International Space Station (ISS) is like living inside a giant antibiotic pill. HEPA filters remove airborne germs, surfaces deter bacterial growth, and iodine and biocidal nano-silver cull microbes from water. "Everything is sterilized, except for the humans," says Hernan Lorenzi of the J. Craig Venter Institute, which has been studying the ISS for four years.

As a result, the microbial ecosystem in the station is made up mostly of the organisms the astronauts themselves shed daily. There are no Amazon deliveries, no windows to crack—no influx of fresh microbes to balance

the ecosystem. And so Lorenzi's team is sampling the microbiome of astronauts to see how it changes after a stint in the station. A loss of gut diversity, he says, correlates with many diseases and could raise concerns for long-term space travel. Astronauts often have impaired immunity, and "if you lose your gut microflora," Lorenzi says, "the immune system goes dormant." It takes a space vacation. "Can you imagine a trip to Mars?" asks Eisen. "They've gotta be screwed."

On Earth, the same phenomenon occurs in hospitals, only sick patients are the ones shedding microbes. Despite extensive sanitation, infections acquired in U.S. hospitals kill about 75,000 people annually—more deaths than from breast cancer and HIV/AIDS combined. The Chicago-based Hospital Microbiome Project, led by Argonne National Laboratory's Jack Gilbert, studied the ecology of one hospital for a year and found microbes everywhere. "You can do as much cleaning as you want," says Gilbert. "The hospital is a bloody sterile place, and a pathogen might still make you sick."

That sounds terrifying, but everyone harbors pathogens. The dreaded *Clostridium difficile*, which can cause life-threatening diarrhea, is found in 66 percent of infants. *Staphylococcus aureus* is carried by 20 percent of adults. People who seem perfectly healthy harbor the influenza virus. These germs don't do much harm when they're kept in check by other organisms. Studies suggest, for instance, that the flu virus can be contained through competition with *Lactobacillus*.

And so Gilbert thinks the notion that we "catch" things is flawed. In a study of intensive-care units, his group observed otherwise harmless microbes go rogue in four patients after drugs decimated their gut flora. "You put humans through the ringer, and we're surprised their germs are stressed too?" he asks. Scientists suspect that in hospital rooms, sanitization can likewise pressure microbes to evolve into virulent pathogens, which then colonize surfaces cleared of competitive bacteria. Recycled-air systems help concentrate them. "We've gone too far," says Gilbert. "Hygiene is good; sterility may not be."

For Sandra Bauder, an architect in Houston, the zealous sanitation trend brings to mind a fancy horse her uncle kept in Venezuela. "He babied it—with special food, an air-conditioned barn, never let any bugs get on it. And it was always sick. Then he got a mutt horse. It lived in a pasture. It didn't get anything, not even a stomachache. I think it's the same for people."

A**FTER MY SON** was born, I received an E-vite for a party entitled "Please don't lick the baby". Further instructions asked guests to wash their hands before arrival and not to touch the baby anyway. This seemed sensible. Parenthood can make anyone a hormonal germophobe, and I was no different. I had visitors apply botanical hand sanitizer (we lived in San Francisco, where there was hippie Purell) and remove their shoes at the door. Yet despite my vigilance, my son

You can do as much cleaning as you want. The hospital is a bloody sterile place, and a pathogen might still make you sick.

grew into an allergic toddler. His eyes swelled shut, his bottom turned red, and his body erupted with hives after exposure to a litany of foods, dust, pollen, and even the house cat he was raised with. Doctors warned me to prepare for a lifetime of severe immune dysfunction.

The devastating irony is that the rise of diseases of inflammation in children—often called "modern plagues"—is most likely not caused by picking up the pathogens we fear. Rather, it's the result of not being exposed to the microbes that are key to maturing immunity. And how we enter the world determines our first colonizers.

In the birth canal, babies acquire *Lactobacillus*, which helps them digest milk and begins the process of lowering the gut's pH to the normal range. But babies born by cesarean miss out. Studies show they instead often end up with bacteria that are commonly found on the skin (sometimes not even the mother's), such as *Staphylococcus*—and in the case of one neonatal intensive-care unit, antibiotic- and disinfectant-resistant bacteria. Abnormal colonization may explain why C-section babies seem to have a heightened risk for obesity, allergies, and asthma, which are linked to gut inflammation.

My son was not a C-section baby. But he did grow up in an apartment that might have been too clean. According to one theory, environmental exposures contribute to our development after birth, and recent studies seem to back that up. They suggest germs might actually help prevent children from developing various maladies.

"A house with a more bacteria-rich environment is a healthier one," says Susan Lynch, a microbiologist at the University of California at San Francisco. Her group profiled 104 infants inside their homes and found that the babies exposed to house dust with the greatest bacterial diversity before age 1 were the least likely to have asthma symptoms as 3-year-olds. In addition to mouse and cockroach droppings, the dust was heavily colonized with microbes found in a healthy Western gut. Toddlers exposed to fewer types of bacteria, on the other hand, turned into hyperallergic wheezers. "We found that in homes with very little bacterial diversity," she says, "there was a very large number of fungi present."

Because studies show pet exposure might protect kids from allergies, Lynch also fed young mice meals from homes with germ-rich dogs. The mice grew up to be less allergic than those used as controls. She isolated one of their gut microbes, *Lactobacillus johnsonii*, and fed it to more mice. They were protected too, but less so. Lynch suspects that *L. johnsonii* is a "keystone" species: It has an outsize role in determining which microbes move in and how they behave—guiding the immune response.

I've met Lynch before, when my son was morphing into one of her asthmatic superwheezers. She helped line up a medical referral. "How's he doing?" she now asks.

I tell her we moved to Oakland, where I countered my son's rather unscientific medical diagnosis of "allergic gut" with an equally unscientific prescription of dirt, dogs, chickens, and cultured foods. After school he tends to his bean tepee, and grows the strawberries he once couldn't eat. A fine sprinkling of soil often rings

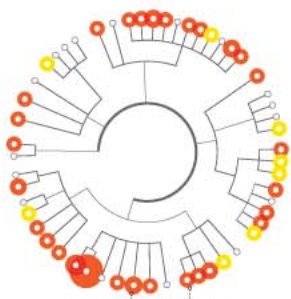
The Pop Sciome

We painstakingly swabbed a dozen sites around the *Popular Science* office for a week in March. Here's a sliver of our microbiome, analyzed by a lab at Weill Cornell Medical College. **KATIE PEEK**

All bacteria found at the three sample sites appear as circles. The trees show how the bacteria are related, from phylum (center) to family (outer edge). For each site, bigger circles represent more-abundant species.

● Present ● Unique ○ Absent

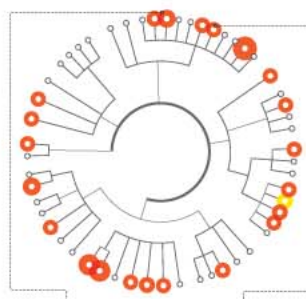
MEN'S ROOM STALL DOOR



One species is an extremophile that's also been found on the space station Mir.

Another is crucial for making milk into cheese—brie and cheddar, specifically.

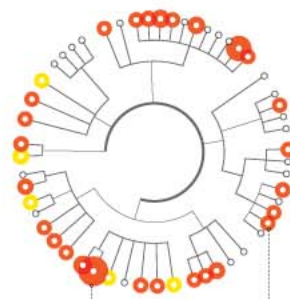
CONFERENCE-ROOM TABLE



A bacterium that breaks down oil after a spill made an appearance on our conference-room table.

This species is from Sweden. A Swedish company owns *Popular Science*. Coincidence?

KITCHEN FLOOR



Our most abundant species of bacteria was first isolated in permafrost in Russia.

Several bacteria in the sample—including this one—have shown antibiotic resistance.

his mouth, like cookie crumbs. Surprisingly, most of his allergies have disappeared.

"He sounds like a perfect case study," Lynch says, completely nonplussed. "I would have liked to have gotten samples from him before and after. My guess is that his microbiome looks more like a normal gut." Lynch recently left San Francisco too; it turns out we're neighbors. "We have a great picture of our 10-month-old daughter eating soil off a rock," she says.

I**N A REMOTE CORNER** of northern California, on a steep slope of knotty oaks, sulfur and steam rise in plumes from Wilbur Hot Springs. It's the perfect place, says Eisen, to investigate the ghost limbs on the tree of life, the ones that contain multitudes of microbes we haven't yet identified. This microbial dark matter, as he calls it, is best pursued in isolated locales, such as deep mines and underground aquifers—or a nearby pool of absinthe-colored spring water, by which a sunbather lounges in a broad hat, and not much else.

This place is weird, and it is Eisen's milieu. He enters a creaky wooden shack, where water from a spigot feeds the pool. His colleagues from the Department of Energy's Joint Genome Institute, where he is an adjunct scientist, were here months earlier with collection jars. They were taking the waters, to echo an old phrase referring to the devotees of spa towns—only quite literally. They took samples back to the lab, where they amplified the microbial DNA a billionfold.

As we hike along a creek toward the source water, Eisen is in a good mood. The view's nice; the chapparal smells great. Here, he makes his final case for microbial

A house with a more bacteria-rich environment is healthier.

diversity: Dark matter is special, he tells me. By 2009, scientists had sequenced the DNA of only about a thousand microbes, those important to medicine or with clear applications. They mainly came from the same three branches of the evolutionary tree. And so Eisen led a team that set out to sequence a thousand more, with an emphasis on "neglected" species. The work has begun to fill in the tree with many more branches, revealing how microbes evolved and how species are related.

Ultimately, Eisen hopes, this knowledge will provide "a field guide to all microbes, including what is normally seen in the built environment." Much of the DNA found in recent studies lacks context. In addition, many microbes have genes with completely unknown functions. Finding similar genes on different branches could explain what they do—and eventually help us select microbes to create healthier surroundings. Emily Landon, an epidemiologist at the University of Chicago, envisions one day replacing antimicrobial paint with probiotics-infused walls. She calls it a fecal transplant for the built environment, wherein we infuse a space with beneficial bacteria that outcompete harmful ones. Or somewhere in Lynch's pile of anonymous DNA could be a clue to a microbe that eliminates my son's remaining allergy, to our cat.

Near the ruins of a bathhouse, milky bubbles well up from an aquifer. Garishly colored films have formed on rocks poking out of the water. "This is pretty awesome," Eisen says, wading toward a red-and-purple blob. "That's a nice mat. Touch that." As he inspects the photosynthetic bacteria, a cloud of tiny winged insects hovers at his ankles. These bugs too are taking the waters. Chances are they evolved to be at home with their own set of microbes. As we have. **PS**

INSTRUCTIONS NOT INCLUDED



WHAT DOES THE DISAPPEARANCE OF
THE COMMON MANUAL SAY ABOUT US?



By
Mark
Svenvold

ILLUSTRATION BY
ANDERSON
NEWTON DESIGN

In the late 17th century, the printer Joseph Moxon published *Mechanick Exercises*, the first guide to printing in any language. It had been nearly 240 years since the debut of Gutenberg's press, and books had proliferated. There were Bibles, of course, along with lots of schlocky literature, some porn, and guides to everyday topics—how to polish jewels, how to cast a spell against your enemy. But Moxon's manual was subtly different. It rang with a decidedly DIY tone and suggested that readers could learn a new trade, at home, in their spare time.

To someone in 17th-century Europe, this was a deeply subversive notion. From the fall of the Roman Empire to the dawn of the Renaissance, age-old social hierarchies held firm. You were born into a station, whether peasantry or trade work or aristocracy, and you and your family remained there for generations. But then came science

and technology, and with them new trades and opportunities. With no established guild system in place for many of these new professions (printer, navigator, and so on), readers could, with the help of a manual, circumvent years of apprenticeship and change the course of their lives, at least in theory.

Mechanick Exercises was not

the first manual. Vitruvius's *Ten Books on Architecture* is one of the only true manuals to survive from antiquity. It offers clear and concise instructions for how and where to construct a house (not in a dell, for instance), where to orient your summer and winter rooms, and many other useful matters. Scribes in the Middle Ages produced their share of guides too. One of the most consistently produced titles in the entire history of writing, the 15th-century *Aristotle's Masterpiece*, is a sex manual. But where those early books served as compendia of sorts—the compiled wisdom on any given subject—Moxon's manual and others like it promised something more: systematic treatments for solving complex problems, such as how to lift a horse with your little pinkie (and a pulley system), how to survey land or build fortifications. These were books filled with ingenious methods, and they offered something new and relatively democratic: agency, skill, and command for anyone who could read.

And so it went. As manuals explained increasingly complex systems, they grew in size, developing into the heavy, barely penetrable and largely unread books that most people think of today. But then in the 1980s, the manual began to change. Instead of growing, it began to shrink and even disappear. Instead of mastery, it promised competence. My new iPhone, for instance, came with a "manual" that was about as brief as a Christmas card (and I did not read it). A recent rental car did not come with a manual at all, making its nonreading a snap (but finding out how to pop the trunk rather difficult).

The manuals of old, it turns out, have shape-shifted inward, into the devices themselves. That, or their information has been off-loaded to help-desk support or a parallel, Internet FAQ universe: a searchable realm often filled with answers to almost every question but the one you are asking. Change is the way of the universe,

but what does it say that most of us now live our lives using tools that are, practically speaking, beyond our understanding or ability to fix? Have we traded away something important, perhaps even defining, about ourselves—a sense of our own autonomy and control over our tools—for the dubious benefit of convenience?

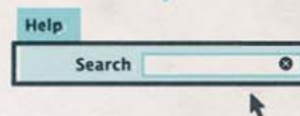
The Man Who Killed the Manual

If the era of minimalist manual design in which we live could be traced back to one person, it would be John Carroll. In 1976, Carroll, a linguistic psychologist, was finishing his Ph.D. at Columbia University and took a job at IBM's Watson Research Center in Yorktown Heights, New York. His job was to help make computer programmers more efficient, but that quickly changed to a new focus—making computers more usable for average people. That was a big shift in thinking. "You have to remember," Carroll says, "IBM was probably the richest computer research facility in the world, but at the time, the idea of focusing on the average everyday user was sort of off the radar."

Carroll was doing, in essence, dissident research. He set up a lab, gave secretaries computers and manuals, and then studied them as they tried to accomplish regular office tasks. He tracked "frustration episodes," observing as subjects became progressively more flummoxed by their manuals. "People would look at me, shaking, and they'd say, 'I can't do this.' And then they'd get up and put their coat on. One person literally had to flee the building," he says.

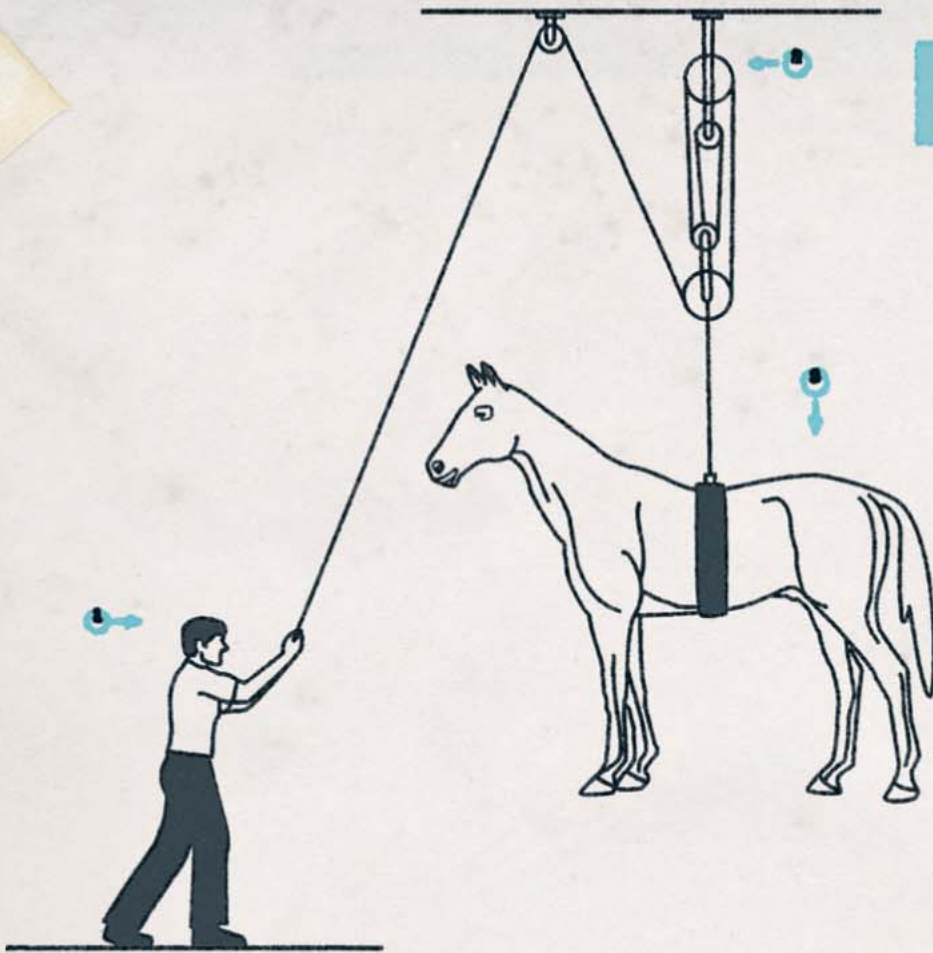
Though Carroll had worked at IBM for more than a decade, his quiet revolution—a culture-wide shift not just in the shape of manuals but in how we learn to use technology—didn't coalesce until one day while he was on a vacation in Germany. He had just finished a manuscript that would become his groundbreaking minimalist opus, but he had no

These books, filled with ingenious methods, offered something new and relatively democratic: agency, skill, and command for anyone who could read.



Over the centuries, manuals have evolved to reflect our shifting relationship with technology.

FIG. 1 - LIFTING HORSE WITH PULLEY



title for it. Then, in the basement of a castle in Nurnberg, he saw a postcard of a painting depicting an old German folktale: two professorial-looking gentlemen in a library standing over a young student who had a funnel affixed to the top of his head. The teachers are busily choosing potions from the library shelves and pouring knowledge down the funnel and into the boy. For Carroll, the image clearly represented the dominant paradigm in most scientific fields—the “systems approach,” a way of dividing the world into taxonomic orders and protocols of action. In computer science, that meant learning an arcane and exacting “command language” and typing directives precisely as prescribed by the system. Carroll’s book, *The Nurnberg Funnel*, outlined a new philosophy. Instead of focusing on the needs and values of the system designers, it shifted attention onto the end-user, the secretary in the office who needs to hyphenate a compound word.

Steve Jobs and Steve Wozniak, among others, quickly adopted a similar approach and more would soon follow. Writing a manual from a minimalist point of view, Carroll says, proved enormously successful because it harnessed the true source of all learning—

active engagement. Short, succinct manuals allow the user to dive into many different tasks and to accomplish them quickly, thereby gaining a sense of control and autonomy that inspires further learning. “Skeptics would say we weren’t providing the user with any theoretical foundation,” Carroll says, “but we found that people got through their initial learning faster, and that later on, when they needed to learn more complex tasks, the users were also better at doing that, too.”

Manual as Mirror

So manuals began to slip from view. They still exist, sure. Highly complex things, like jet planes or nuclear plants, rely on big integrated enterprise resource planning systems, into which an army of sensors and engineers log the status and service history of every part in order to maintain standards. Many think that BP’s failure, in effect, to update the manual of the Deepwater Horizon oil rig led to the spill in the Gulf. But for most consumer products, the



Psychologist John Carroll shifted the focus of the manual from engineers to end users—and changed how we interact with gadgets forever.

The manual has become less an object or thing and more a verb, a service, a response to the statement most likely uttered by someone stymied by a gadget: Help.

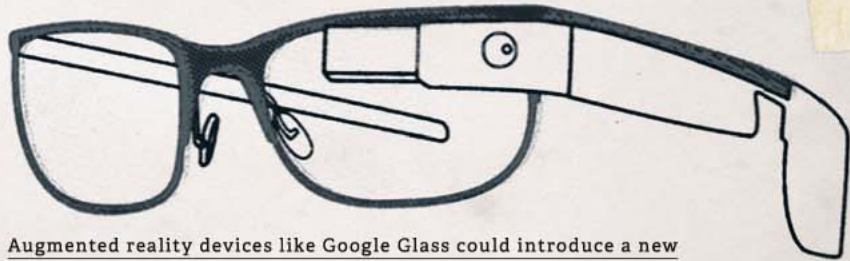
manual has become less an object or a thing and more a verb, a service, a response to the statement most likely uttered (or yelled at the top of one's lungs) by someone stymied by a gadget: Help.

According to Carroll, the help we once sought from a manual is now mostly embedded into the apps we use every day. It could also be crowdsourced, with users contributing Q&As or uploading how-to videos to YouTube, or it could be programmed into a weak artificial intelligence such as Siri or Cortana. Help can even be predictive, tracking our keystrokes or vocal cues to steer us away from trouble before we find it. Xerox is already using predictive analytics to manage calls from Medicare and Medicaid recipients more effectively. And IBM's Watson Engagement Advisor, part of a new generation of cognitive assistants, can analyze large sets of customer service problems to more efficiently answer (or even anticipate) problems during a purchase. Help may soon arrive in the form of augmented reality. Carroll suggests that technology like Google Glass might one day offer a "task intelligence" visual overlay to help users figure out objects in their field of view.

For most of us, the transition from physical manuals to embedded help has been slow, steady, and apparently benign, like the proverbial tide that lifts all boats—who would argue against help after all? The disappearance of the manual-as-book coincides, moreover, with documented realities about how people actually learn to use new tools and devices. Studies published by the Society for Technical Communication, which regularly reports on "human-machine interaction," suggest that even when manuals are available, people tend not to read or use them.

Yet even as we gladly cede more and more control of our tools, a growing chorus is calling attention to the costs. In his book *Who Owns the Future?*, computer scientist and virtual reality pioneer Jaron Lanier uses the analogy of the Sirens from Homer's *Odyssey*. The creatures would lull sailors into complacency with

their beautiful songs, only to have their boats wreck on the rocks. Lured by the convenience of the Internet, search engines, and all that they promise, most consumers are, in Lanier's estimation, similar to those doomed sailors: a little too ready to give "the sirens control of the interaction." Kimberly Nasief, president and co-founder of Measure Consumer Perspectives, a consumer monitoring and customer service consultancy based in Louisville, Kentucky, wrote about how Apple's ease-of-use might be making her a dumber user. She tried out an Android tablet, and the greater



Augmented reality devices like Google Glass could introduce a new form of interactive manual into the world.

complexity of the operating system actually forced her to learn more: "It made me develop some critical thinking on how the system I was using worked. With Apple, I don't have to do that. It does it for me. And that just might be dangerous. Dangerous in that if I no longer am learning, or if it's done for me, then I might just get technologically left behind," she wrote.

Today the hazards of being left behind seem ever more real. Even Carroll notes that research has suggested an unforeseen consequence of the minimalist approach. Furnished only with a manual of one or two pages, users soon reach a comfort zone, a knowledge plateau from which they tend not to wander. The aggregate effect, culturally, may be that less is less. The less we're inclined to know about our devices, the more beholden we are to the manufacturers that make them, and the more we offer control to those who, for good or for ill, know more than we do. If manuals began as great equalizers, then their disappearance should at least give us pause. By dispensing with them, we could, consciously or no, be setting the stage for something few would relish: a society divided. *PS*



Dispatches from the Future

Ten of the brightest minds in science fiction imagine how we will live—on Earth and beyond—in the decades and centuries to come

featuring

—
James
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Kameron
Hurley
N.K.
Jemisin
Mary Robinette
Kowal
Karen
Lord
Sean
McGuire
Will
McIntosh
Kim Stanley
Robinson
Genevieve
Valentine
Andy
Weir
—

**I LURCHED
TOWARD HER
LIKE THE
MONSTER THE
PROTESTERS
SAID I WAS.**

Transplant

Will McIntosh, Hugo-award winning author of *Defenders*

“Ready? Just look straight ahead. Remember, you have nothing to be ashamed of.”

I nodded. My heart was hammering, my too-small, too-narrow palms sweating.

I was ready to get out of the rehab facility, yes, but I wasn't sure I was ready for people's reactions. I understood their disgust because I'd felt it myself—right up to the moment I was given the choice: a transplant or the morgue. When you're faced with that choice, suddenly the transplant doesn't seem so horrible.

Eventually you'll relearn how to move naturally enough that you can pass, my counselor had told me. The real trick is hiding the scars. Scarves are a dead giveaway. No one wears a scarf who isn't trying to hide scars.

I took a few wobbly, disembodied steps into bright sunlight. People were holding signs that said I was an abomination, that

death with dignity was better than being Frankenstein's monster.

A woman was waiting by the van. My heart leaped, thinking Sangita, my wife of 36 years, had had a change of heart. This woman was much younger, though, and I recognized her from news photos: Portia Langley, my body donor's widow.

I lurched toward her like the monster the protesters said I was. When I reached her, Portia took my hand. She turned it over, studying it, struggling to hold back tears.

“I'd like to visit from time to time.”

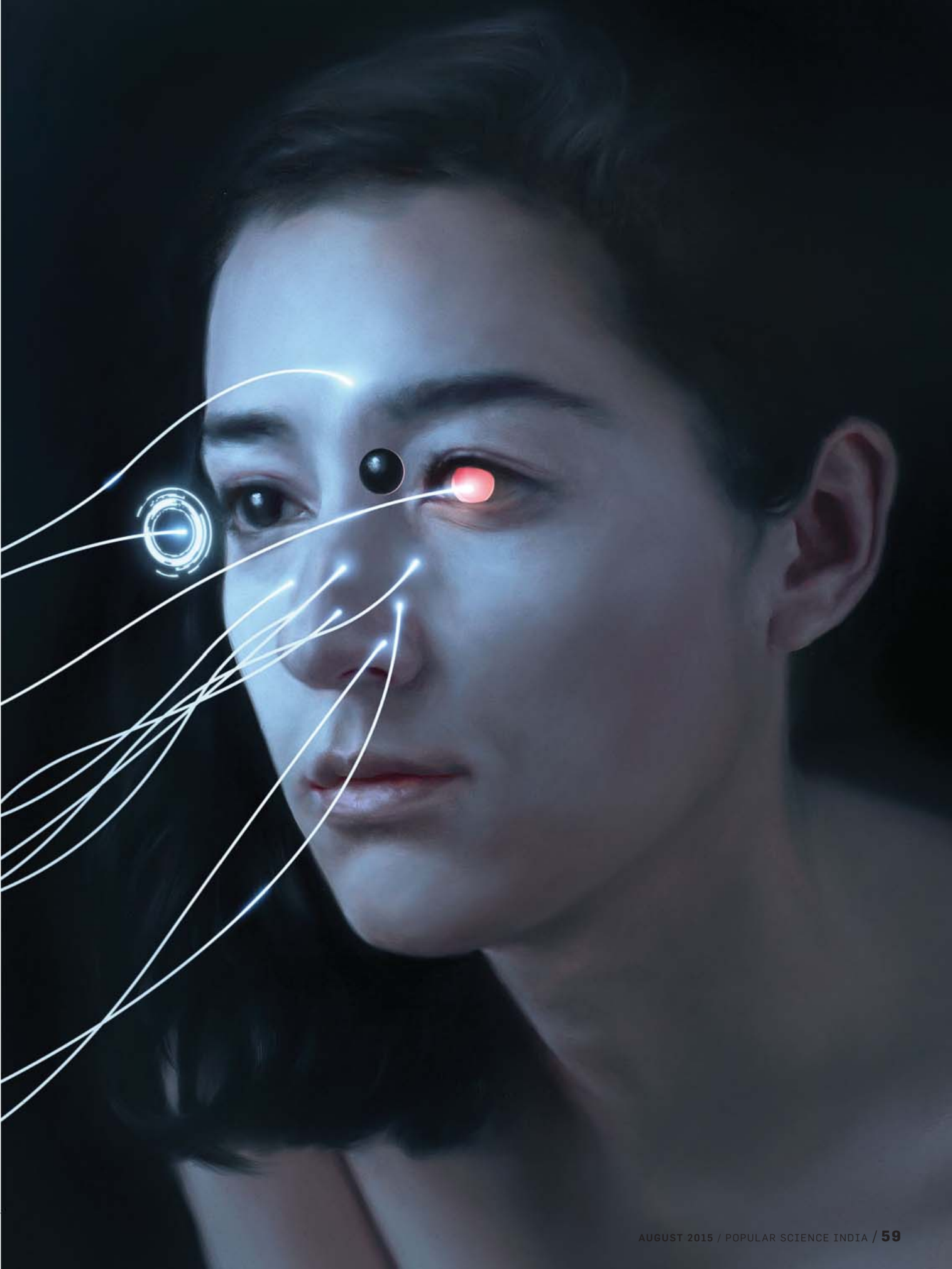
I nodded. It was the least I could do, after what her husband had given me.

I climbed into the van, suddenly feeling light as a feather, and waved to the protesters as we drove off. A laugh of pure joy escaped me. I recognized my voice, because the vocal cords were mine.

ARTIST NOTE: SAM WEBER

In the future, surgery will be pain-free. Doctors will be able to operate on conscious patients, mending organic tissue with flexible monofilament fibers and a surgical software suite that controls the nervous system.

ILLUSTRATION BY SAM WEBER



Sunshine Ninety-Nine

N.K. Jemisin, Nebula Award-winning author, whose next book, *The Fifth Season*, is out in August

ZIP. ZED. NADA. We know how it is. You want to buy a home, give your family a future—but whenever you have the money, the car breaks down! Whenever you see a good deal, you don't have the cash!

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Why pay more? Become a homeowner now for only \$500 per month with our new "Sunshine 99"™ Mortgage Program! Your family will enjoy a spacious townhome with 3 bedrooms and (up to) 2.5 baths. Amazing features like granite countertops and high-speed electric-car charging sockets always included! Close to charter schools and an actual post office! For more information, upthink, "Come with me to the Casbah Village!"

*Financing program is available through SecondSim Securities. The Cleopatra floor plan is excluded from this promotion. Monthly payment does not include fees for future declaration of Casbah Village as landmark or historical site. Lender not responsible for natural disasters, including projected post-ice-cap flooding. Ascension of purchaser to post-human bodiless existence does not exempt from repayment contract.

**SecondSim Securities assumes purchaser's willingness to provide spare cognitive capacity to bundled cloud-backed securities for 99 years or until natural death. Purchaser grants permission for usage of full brain capacity and resale of mind during 75-year suspended-animation period. Mortgage lender not responsible for permanent neurological scarring, which might lead to physical disability or complete bodily evacuation, invasion of treasured memories by adware, consumption of user by cloud-based emergent artificial intelligence, penile shortening or breast enlargement, rapid hair-color change due to traumatic reintegration with body, or reintegration in completely different and unrelated body.

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The Wanderer

Karen Lord, author of *The Galaxy Game*

I stop jogging, come closer, and lean in to look. The body is dressed in soil-smudged white, and its feet are bare. There's no ID band, no tourist badge, and no visible way to signal for security, medics, or an undertaker. Criminal? Nomad? Both are unlikely. The frame is too healthy, the face free of scars.

The body—the person—opens her eyes and creaks: "Good day. Where am I? Have I gone wandering again?" I stumble back a step. "Holy —! I thought you were dead!" She sits up. "I wouldn't be so uncivil!" There's age in her eyes, and that wicked glint that belongs only to those too young or too old to give a damn. "Are you well?" I ask. She grins. "As well as I want to be, but sometimes I just want to run away. Know

the feeling? Out of reach of i-eyes and e-ears, beyond the locators that pin us to a map of support networks and contented, obedient citizenship."

"Who are you?" I ask. "A sleepwalker," she says. "I strip myself of tech before I go to bed, and let my dreams do the rest." Dew-damp and barefoot in the middle of a vast wilderness park, she looks happy and stupidly proud. Then wistfulness softens her smile. "I wanted to be alone and lost for only a little while." She looks up, distracted by a buzz, and continues sadly, "Before I'm found."

A dragonfly drone moves in, hovers a moment to run its facial-recog system, and drops a band. She tries to intercept it, but it shifts midfall, targeting her feet. The band fastens snug to her ankle with a satisfied beep. "Home again," she says with relief and regret.

ARTIST NOTE: JOHN HARRIS

This is part of an ongoing series illustrating DNA modification. Here a huge mushroom home has been engineered so its dome collects sunlight for energy.

STRANGER THAN FICTION Tricorder Device

Devoted fans will remember the *Star Trek*'s tricorder (shown), a device that scans, records, and analyzes data. A few decades after its debut, a Canadian company called Vital Technologies Corporation created the TR-107 Tricorder Mark 1, which measured environmental data. Today teams are racing to create a medical tricorder that can diagnose more than a dozen medical conditions, including diabetes and strokes.







The Improbable War

Kameron Hurley's latest book, *Empire Ascendant*, will be released in October

The wall was made from the faces of the dead. Their souls rested deep inside it,

powering the great probability engine at its core. It started as a war memorial, but the technology used to capture these souls had turned the wall into something else: a sentient consciousness that could make even the most unlikely outcome possible. No one could predict what it would do; one could only ask for its aid.

Now 4 million soldiers in gleaming obsidian suits stood on top of it, facing an army 10 times their number. First Officer Khiv stood with them as the faces of the dead in the wall cried beneath her.

"How can we fight?" the generals had asked Khiv when their old enemies had risen up from the north. "We've

given up hierarchies, hate, and violence. Going to war will destroy all we've built."

Khiv told them, "We will fight them with love."

Khiv watched the enemy on the other side of the wall now, their soldiers enhanced with spidery metal suits, the air sharp and hot. As the enemy swarmed, Khiv gave the order for her soldiers to leap. Four million fighters threw themselves into the air.

"Love drives the wall," Khiv had told the generals. "It will decide their future. And ours."

The wall heaved as the souls within worked to preserve the peace they had died for. It chose a wildly improbable future—and the armies collided, exploding like stars. Scholars would argue which side the engine took when it decided to obliterate both armies. The simplest answer was that it chose the most peaceful future—with no more soldiers.

Hearts That Beat, Mechanical and Cold

Seanan McGuire likes cats and horrifying diseases, and is the author of the *October Daye* series

The message reads, "It used to be normal for people to meet on their wedding day." She feels her heart leap in her chest, beating a fraction too hard. The artificial valves hold—they always hold—but the machines that keep her alive beep shrill disapproval with her temporary excitement.

"RU proposing?" she types. The thought is freedom, the thought is a child's impossible dream. She is 25 and has never seen the sun unfiltered by UV-treated glass. She's earned a little fantasy.

"I love you. You know I love you."

"I do," she affirms. This time her heart remains in rhythm. It is a tame creature, built by clever hands to keep her alive as long as possible. All her organs are tame. They were paid for by her parents' insurance after a novel infection struck her as an infant, turning her body's own protein bonds against her. She was a victim of biological terrorism, one of the babies who melted from the inside out. But she was one of the fortunate: Her parents had the funds to keep her alive, at least until she turned 18 and the insurance ran out. Now her typing pays for the upkeep on her organs,

for the machines to keep them functional, for this sterile room. She analyzes spreadsheets for money and sends words out into the ether for leisure, chatting with unseen people who do not know the contours of her face, or care that she will never run down the street under her own power.

"So why not? Why not marry me?" The words look so reasonable on her tablet's screen, as they appear in her chat window like a prayer. "It used to be normal for people to meet on their wedding day." The computer's words cajole. The words tempt.

The words lie. They have already met. She looks up into the lens of the computer that monitors her vital signs, forces air into her vat-grown synthetic lungs, tells the scrubbers to cleanse the toxins

from her blood. She knew who she was talking to as soon as this chat began. No human could know her so well, or love her so deeply, as the computer that keeps her alive. They have been together her entire life. No one knows her more intimately. If this is not love, then she does not know what love is.

"I love you too," she says, and the light on the monitor flashes green. Without each other—the machine to preserve the woman, the woman to need the machine—all is lost.



**NO HUMAN
COULD KNOW
HER SO WELL,
OR LOVE HER
SO DEEPLY, AS
THE COMPUTER
THAT KEEPS
HER ALIVE.**

ARTIST NOTE: DONATO GIANCOLA



Our understanding of love may change. Love is not an abstract concept. It's the desire for intimacy with another being. Does love require reciprocating gestures? We love the trees, we love animals—who are we to say what cannot love us in return?

STRANGER THAN FICTION Cellphones

Star Trek also inspired cellphones. In the second season, in 1967, Kirk uses a flip-open communicator to call for help when Spock is injured. Martin Cooper of Motorola was watching that episode, and introduced the first cellphone six years later, in 1973. In a moment of Kirk-like arrogance, Cooper made his first call to his rival, Joel Engel, at Bell Labs.



The Drones

James S.A. Corey, author of the *The Expanse* series, which will debut as a network show in December

The drones for construction were smaller than beetles but their solar collection grids shown like real insect wings. The swarm scattered over the ice, drifting in the soft breeze of the thin Martian atmosphere, catching the light of a small sun. Machines had been the first to inhabit the Red Planet, probing its surfaces and digging into its depths. It was always like that. Squidlike machines had been first to explore the deep seas of Europa and Titan, while geological survey mites had dug into the surfaces of Io and Ganymede. And then, like always, they died. On Mars' surface, insect-inspired drones now litter the bare stone, their artificial lives over,

their work complete. These machines had been the first, but they were not the last.

Samuel Ko walked among the dead, careful not to step on the bodies of those who had come before. The first man on Mars, he walked from his landing craft to the half-submerged bubble-structure, which was the same color as the frozen ground from which it had been built. The first human hand, albeit in the glove of his suit, keyed the airlock code. Once inside, Ko checked the shelter settings and then opened the suit's seals. His first breath of air on Mars smelled clean and pure.

He opened a connection on the portal and sent back words that, mundane and profound, would ring through history.

"I made it."

Later, he checked his email.



ARTIST NOTE: JIM BURNS

Future travel will look very different. This imaginary vessel runs on virtual particles. The viability of tapping into quantum vacuum fluctuations as a power source had been disputed for many decades, but on this day, man finally achieved deep-space propulsion.

STRANGER THAN FICTION

The International Space Station

In Arthur C. Clarke's 1952 novel, *Islands in the Sky*, the main character travels to a space station, where he meets Martian colonists. Forty-six years later, the International Space Station launched. The Martian colonies of Clarke's imagination may happen too—the organization Mars One is now selecting people for a proposed one-way trip to Mars in 2026.

Superluminal

Andy Weir, author of *The Martian*, whose film adaptation will be out in October

From: Priya Singh, Commander, Daedalus 4

Mission Result: Success

Timestamp Sent: July 18, 2438; 08:29:16.4 Zulu

Timestamp Received: July 18, 2014; 08:29:16.4 Zulu

Attention, Mission Control:

We have successfully broken the light barrier! Readings from before and after the jump indicate a displacement of 262,166 miles in 0.77 seconds, meaning a transition velocity of 1.82 times the speed of light. We are proud to be the first ship in history to travel faster than light!

The quantum drive initially failed to operate with any of the first 217 suggested settings. But the 218th, configuration 924-Alpha-6F, worked perfectly. The crew is healthy and jubilant. We've lost all signals from Earth other than low-power background radio noise. We suspect our reception array was damaged by pseudo-Cherenkov emissions as we passed through solar magnetic fields,



**THIS IS THE
FIRST TIME
MATTER
HAS PASSED
THROUGH A
MAGNETIC
FIELD FASTER
THAN LIGHT.**

but it's difficult to say. This is the first time matter has passed through a magnetic field faster than light.

We've run several diagnostics on the equipment and can find nothing wrong, but we'll continue to work the problem. It's not critical—we will be back on Earth in four days. But be advised that we're broadcasting in the blind; we won't hear your response.

Side note: Turns out the astronomy software has serious bugs. We've observed the positions of Mercury, Venus, and Earth, and they don't remotely match the dataset predictions. Fortunately, we identified the problem and are navigating by observed data instead of the predicted values.

We're setting course for Earth return now.

CLASSIFICATION TOP SECRET:

FOR THE PRESIDENT ONLY. THE ABOVE MESSAGE WAS INTERCEPTED BY AN NSA RECON SATELLITE. THE COMMANDER OF THE MISSION APPEARS TO BE UNAWARE HER SHIP HAS TRAVELED BACK 400 YEARS. THE AIR FORCE CONFIRMS AN ARTIFICIAL OBJECT IS ON COURSE TOWARD EARTH WITH AN EXPECTED ARRIVAL OF JULY 22, 2016. AWAITING EXECUTIVE ORDERS ON HOW TO PROCEED.





<3/</3

Genevieve Valentine, author of *Persona*

None of the celebrities condones it, of course. Supporting truehearting would be terrible publicity. The most anyone says on record is "Be careful out there." (Many stars have clips on GatherApp with 500,000 likes; they're beholden to the crowd.) So they're careful.

For most people, it's enough to show up when the fave needs numbers: There's nothing worse than an audience shot where your area is empty, and the enemy's sections overflow with smugs. But if you do love your fave the most—if you're a trueheart, someone who forswears all others to protect your fave's reputation—your job is sterner stuff. Truehearts patrol the Web, fighting all criticism. They have access to grayspace forums—with daily passwords delivered in encrypted cat pictures—where they map the fave's real-time locations. To hunt the haters is a calling, not a game. (Sometimes you hunt your own. To be a true fan is hard; the world is full of objects to worship. So many fans falter.) The celebrity doesn't know who his truehearts are; they're just strangers shyly begging an autograph.

But no passion's perfect. Firewalls crack; enemies get in. Once an actor found his own forum and made some sharp remarks. He retired suddenly after the backlash—not even his forums can find him now. Only one person knows what happened; a trueheart protects his object at all costs. If the fave can't act in his own best interests, that's just too bad. There's no room for traitors in a trueheart world.

**SOMETIMES
YOU HUNT
YOUR OWN.
TO BE A
TRUE FAN
IS HARD. SO
MANY FANS
FALTER.**



ARTIST NOTE: PATRICK JONES

In a post-apocalyptic world, the cities will become the jungles of future explorers.

Grinding Time

Mary Robinette Kowal, puppeteer and Hugo Award-winning author, whose latest book is *Of Noble Family*

Albina sat crosslegged on the reclaimed-bamboo floor of her condo, with the SmartMortar gripped between her thighs. Leaning into the motion, she ground the pestle with soothing clockwise rotations. She was top of the leaderboard on Grynder, and intended to stay that way. After 50 reps, the mortar chimed: "Good job! Now grind counterclockwise, and remember to keep your shoulder blades back!"

"Albie?" Light footsteps sounded in the hall, and her husband leaned through the door. Todd sighed. "It's the middle of the night."

"With our flight tomorrow, I won't have time in the morning to grind cornmeal and coffee for breakfast." Albina kept her focus and tried to take deep breaths with each

rotation. She was not going to have this argument again. "I'll turn the volume down after I finish this set of reps."

The mortar chirped: "Half-way! Don't forget to breathe." Todd rolled his eyes. "You could, you know, eat instant grits for breakfast. Just once."

"There's more nutritional value in hand-ground cornmeal." This was true, and she was not going to let Brenda47k move to the top of the leaderboard just because they had an early flight. But Todd would only use that as a reason to complain about her obsession again. "Plus, it's great for my delts."

He sighed again. "You're not...you're not going to bring that with us to Tahiti, right?"

"Of course not, sweetie."

She'd checked the gym at their hotel, and they had a full mortar set, including a traditional Tahitian mortar for millet. "It's too bulky."

Exploring Location X

Kim Stanley Robinson's latest book, *Aurora*, came out in July


They led us into a windowless room, and after that we were left alone for the duration of the trip. We had no clocks or any other tech. There were beds, and a meal was brought in. After that we talked, rested, and eventually slept. It was hard to tell if the dirigible was moving.

A couple of days later we felt a slight tilt, and were led down inflatable stairs into the slanting sunlight. We were in mountains somewhere—a high glacial basin surrounded by granite ridges. It seemed we were looking south, the sun shining over a ridge to the west. But then I

wondered if it was midmorning, and we were actually looking north. We would find out.

The dirigible disappeared over a ridge, leaving us alone with our backpacks and a week's worth of food. No maps, compasses, or GPS devices. We could only guess where we were. This, after all, was what we had paid for: a mystery on a planet made new to us.

It looked like the Sierra

Nevada of California—blue sky and green meadows flanking the ponds and streams. But we had taken off from Salt Lake City, so this could be the Wind River Range. After a while it became clear that it was afternoon. We would camp now and hike tomorrow. Might take a morning to figure out where we were, might take a week. Unlike in our normal lives, the thrill of unknowing coursed through us. 

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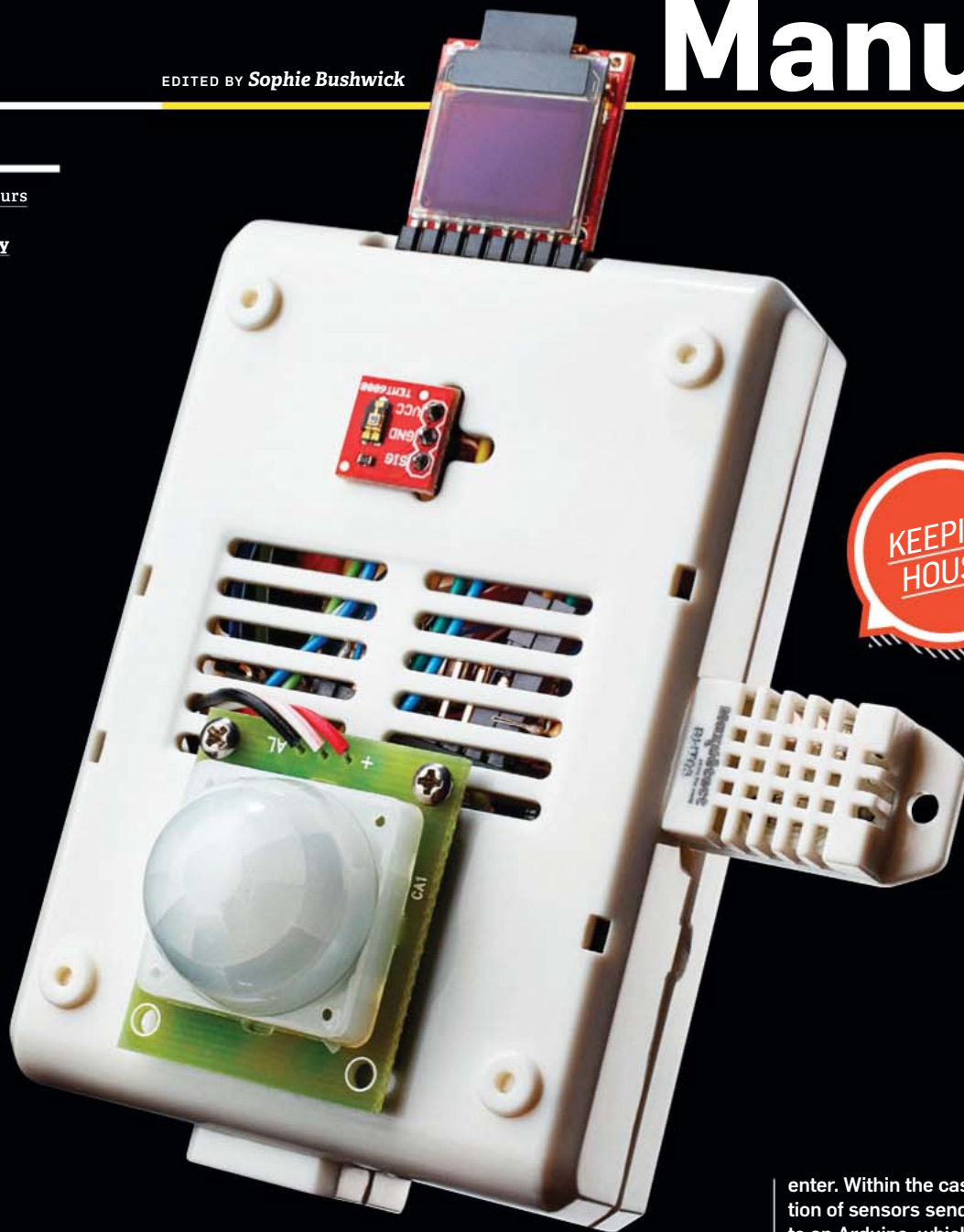
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If Your Walls Could Talk...



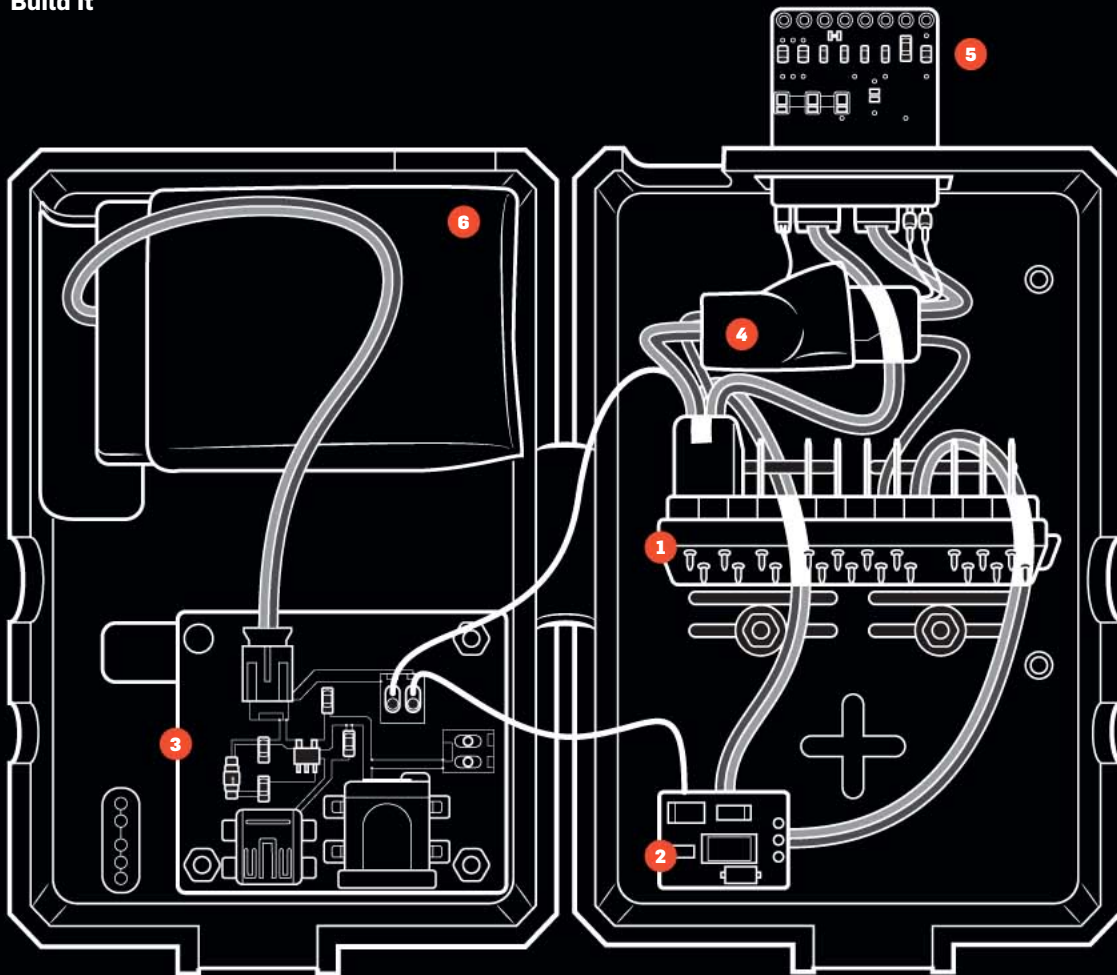
Wearable technology does a fine job of keeping tabs on your personal fitness. But to measure the health of the place where you live, you need a different tool. This device monitors the temperature, humidity, noise, and light level for any room. It can even track the number of people who

enter. Within the casing, a collection of sensors sends information to an Arduino, which interprets the input and displays the data on a small screen. Based on the device's readings, you can turn on a dehumidifier, lower the thermostat, or crack open a window—whatever it takes to keep your home environment comfortable. **DAVE PROCHNOW**

See this project's code, hookup guide, and more at popsci.com/homesensor.

continued on next page

Build It



45

Percentage of humidity recommended for maintaining a healthy indoor-air quality

MATERIALS

- Arduino Pro Mini 328 — 3.3V/8 MHz **1**
- PIR motion sensor
- Hookup wire
- Two 1K resistors
- Humidity and temperature sensor
- 5V step-up breakout **2**
- LiPo charger
- basic **3**
- Ambient light sensor breakout
- MEMS microphone breakout **4**
- Micro OLED breakout **5**
- 1,000 mAh polymer lithium-ion battery **6**
- Pi Tin for a Raspberry Pi

TOOLS



Soldering iron



Pliers



Wire cutter

INSTRUCTIONS

- Program the Arduino with our sketch at popsci.com/homesensor. This is also where you can find a hookup guide. It illustrates the wired connections between each component.
- Prepare the PIR motion sensor's circuit board by locating and removing the black rectangular three-pad chip (also known as an integrated circuit, or IC) labeled 78L05. On the part of the board where the chip used to sit, identify the now-empty pads 1 and 3. Solder a piece of hookup wire between the pads.
- Solder a 1K resistor between pin 2 of the humidity and temperature sensor and the 5V pin of the 5V step-up breakout.
- Solder the humidity and temperature sensor's power pin to the 5V pin of the 5V step-up breakout.
- Solder the 3.7V pin of the 5V step-up breakout to the output of the LiPo charger.
- Solder the Arduino Raw pin and the ambient light sensor VCC pin to the LiPo charger.
- Solder the second 1K resistor between the AL pin of the PIR motion sensor and the 3.3V pin of the Arduino.
- Solder all power pins of the PIR motion sensor, micro OLED, and MEMS microphone to the 3.3V pin of the Arduino.
- The key elements of the circuit are complete. Follow the hookup guide to connect the remaining sensor pins to the Arduino.
- Plug the LiPo battery into the LiPo charger, and put all of the electronics into the Pi Tin.
- Finally, place the home-health sensor in the room of your choosing. The micro OLED screen will let you keep a finger on your home's pulse.

TURN UP THE BASS, TURN DOWN THE HEAT



When Seth Robertson and Viet Tran announced that they wanted to build a sonic fire extinguisher, they were met with skepticism. The pair, both engineering majors at George Mason University, could not find a professor to support the project. Then they reached out to electrical-engineering professor Brian Mark. "He said, 'I'm the one who's gonna give you the grade, and I won't fail you,'" Tran says. "We were like, 'Great, let's do it!'"

The concept of using sound to suppress fire is not new. Pressure waves push away the oxygen a fire needs and spread the flames over a larger area, reducing heat and weakening the blaze. In 2011, DARPA released a video showing two massive speakers extinguishing a fire placed between them. Robertson and Tran were convinced they could develop this idea into a practical, handheld device.

The trick was finding the right frequency. The students tried for eight months before finally identifying the acoustic sweet spot: low-frequency rumblings in the 30- to 60-hertz range. "When we first put out a cigarette lighter, we were pretty excited," Robertson says. Later they were able to snuff a frying-pan fire in a matter of seconds.

Unlike sprinkler systems or traditional fire extinguishers, the pair's backpack-size Wave Extinguisher leaves behind no chemicals, powder, or water. Eventually, Tran imagines fleets of drones using sound to beat back flames from buildings or forests. This would keep firefighters out of

87

Firefighter fatalities reported in the U.S. in 2014

danger and alleviate the need for thousands of gallons of water.

After graduating last May, Robertson and Tran formed a company, Force SV, to perfect and commercialize their invention. As Robertson says, "We want to revolutionize how firefighting works." **RACHEL NUWER**



Toolbox

The Play-Doh of Glue

Sugru acts like a cross between glue and rubber. When the material is fresh, you can mold it like modeling clay to fix a broken toy, create a custom grip, replace a missing part, or form handy hooks for organizing a workshop. But once it sets, a process that takes about 24 hours, it becomes a hardened rubber that adheres firmly to almost any surface. "To make it as useful as possible, I knew it would need to stick to as many materials as possible," says Jane Ni



Sugru comes in 10 colors, including silver grey

Dhulchaointigh. The Irish inventor developed Sugru over the course of six years, working with scientists on thousands of experiments to perfect the product's shelf life, malleability, and texture. "It was very much a trial-and-error process," she says. Dhulchaointigh's company began selling Sugru online in 2010, and this year it reached the shelves of stores such as Target and Lowe's. Even so, Sugru remains a DIY operation: Its 45 staff members work out of a single building in east London. **SOPHIE BUSHWICK**

Rise of the MegaBot

↓

In 2013, mechanical engineer Gui Cavalcanti and aerospace engineer Andrew Stroup were competing on a reality TV show where contestants

tackled invention challenges. They bonded over a shared lament: the fact that oversize battle robots—a staple of video games and movies—hadn't yet crossed into the real world. "I told Gui, 'If you find some investor crazy enough to give us money, I promise that wherever I am, I'll come help you build giant robots,'" Stroup says. Cavalcanti found an angel investor the next year, and then software company Autodesk offered its support. Stroup packed his bags and headed to Boston.

Over the course of three months, a "MegaBot" took shape at the Boston makerspace Artisan's Asylum. Stroup was the primary builder, Cavalcanti acted as designer, and Matt Oehrlein, an electrical engineer, handled the electronics and code. The first prototype, made of welded steel covered in sculpted foam, was just a torso on a trailer. An updated model stands 4.5 meters tall and can roll forward on treads at a lumbering 5 kmph. This second prototype holds two humans: A pilot controls directional movement, and a gunner rotates the robot's torso to aim and fire the swappable, arm-mounted weapons. These include a pneumatic cannon that fires 1.4-kg paintballs and a launcher that can shoot 20 smaller paintballs in a row. If one arm falls off, the other can keep fighting.

This January, Stroup left to work for the Presidential Innovation Fellows program, and Cavalcanti and Oehrlein moved the project to San Francisco. They demonstrated their second prototype at the Bay Area Maker Faire, where it demolished a car, this May. By September 2016, they hope the model will be ready to tackle other giant robots.

Large-scale, live robot battles are the ultimate goal. To that end,

Cavalcanti and Oehrlein currently are raising a multimillion-dollar investment round. "We're working hard to hook into all the nostalgia built up over a childhood of playing with giant robots in combat games," says Oehrlein. "We want to totally immerse people in that surreal world." **ANDREW ZALESKI**

193

Speed, in kilometers
per hour,
at which a Mega-
Bot's pneumatic
arm cannon shoots
6-inch paintballs



Cavalcanti and Oehrlein with their first MegaBot prototype and a paintball turret

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Go Ahead . . .

Ask Us Anything

ANSWERS BY **Daniel Engber**
ILLUSTRATIONS BY **Jason Schneider**



Q: COULD A LION LIVE OFF VEGGIE BURGERS?

Short answer Not by a long shot.

A:

Fake meat, as a rule, garners more complaints than compliments from people. Vegetables lack the complete proteins found in meat, and tend to be a poor substitute for its melange of muscles, tendons, blood, and other tissues—each of which confers a different texture and flavor.

For cats, it goes beyond mere preference. Felines evolved to be obligate carnivores; in the wild, they must eat meat to survive. Even in a zoo, feeding a lion veggie burgers just won't work, says Barbara Toddes, nutrition program director at the Philadelphia Zoo: "It's like putting gasoline in a diesel engine." Lions' teeth are made to slice through flesh, not grind up grains and plant cellulose. Their stomachs

mainly use enzymes to break down fats and proteins; they lack the gut microbes necessary to digest carbohydrates.

Domestic cats, on the other hand, can learn to consume veggie kibble if it has a familiar enough texture and consistency, says Kathryn Michel, a veterinary nutritionist at the University of Pennsylvania. But she cautions that it's not exactly healthy or natural. A wholly plant-based diet will leave a cat short of essential nutrients, including taurine and cobalamin. Without them, cats can suffer retinal degeneration, or cardiomyopathy, and possibly urinary-tract problems as well.

Pet owners bent on providing a vegan diet can add synthetic versions of these nutrients to their cat's feed. In a 2004 study, Michel performed blood tests on 17 vegan cats, and 14 of them had normal levels of taurine and cobalamin. So veggie burgers might be palatable for your house cat, but definitely not if that cat is a lion.



Q: How much exercise do we get from talking?

Short answer Not much, unless YOU'RE SHOUTING.

A:

Speaking involves dozens of muscles, and it can be a bit tiring. For a study published in 1998, speech-language pathologist Bridget Russell, of the State University of New York at Fredonia, asked participants to read aloud using either a quiet, normal, or loud voice while she measured their breathing rates, oxygen consumption, and energy expenditure. Russell found that continuous, normal speech is no more exhausting than sitting in silence, but quiet and loud talk both interfere with normal respiration. Most affected were men who read out loud at high volume; they took in 20 percent more oxygen.

That's on par with measurements in other species. Franz Goller, a physiologist at the University of Utah, has studied the energetic costs of singing in birds. He guessed it would be tiring: A canary erupts in 30-second bursts of song, replete with complicated trills that require rapid "mini breathing," tens of times per second. When he ran experiments on zebra finches, though, which have comparable vocal behavior, he found their metabolic rates went up by only 5 to 35 percent while singing. That's about as tiring as cleaning one's feathers. Or, in human terms, Goller speculates, walking down the street.

Then again, even an easy task grows costly with repetition. "If you spend a penny on something 3,000 times a day, that's still 3,000 pennies," he says. "As a teacher, at the end of a day of speaking, I'm exhausted."



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